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**SUPERTOG-JR, A CODE GENERATING TRANSPORT  
GROUP CONSTANTS, ENERGY DEPOSITION  
COEFFICIENTS AND ATOMIC  
DISPLACEMENT CONSTANTS WITH ENDF/B**

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SUPERTOG-JR, A Code generating Transport Group Constants,  
Energy Deposition Coefficients and Atomic Displacement  
Constants with ENDF/B

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SUPERTOG-JR generates (a) the neutron cross sections for neutron transport calculation and (b) the energy deposition coefficients and the atomic displacement cross sections.

The function (a) is the same as in SUPERTOG-3 except the addition of an optional routine generating the inelastic scattering matrix in the level density model. The function (b) developed newly treats both in nearly the same mathematical formulae except for the conversion scheme of kinetic energy of neutrons onto the material atoms. The displacement cross section is calculated with the Lindhard model.

SUPER TOG-JR, ENDF/B ライブライアリを利用する中性子  
輸送群定数, 発熱定数, 原子はじき出し定数の作成コード

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(1977年1月26日受理)

SUPER TOG-JR は(a)中性子輸送計算用群定数の作成, および(b)中性子反応による発熱定数と原子はじき出し定数を作成するコードである。

(a)の機能は連続領域の非弾性散乱減速マトリックスをレベル密度モデルで求めることのできる機能を追加した以外は, SUPER TOG-3 と全く同じである。機能(b)は新らしく追加された機能で, 両者は中性子の運動エネルギーの変換スキームを除いてほとんど同じ形式で扱うことができる。原子はじき出し断面積は Lind hard のモデルを用いて計算している。

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## 1. Introduction

For design and analysis of reactor shield, it is required to estimate various quantities, such as detector reaction rates, biological doses, energy depositions and radiation damages. These quantities are obtained by multiplying the fluxes in the shield by response functions of required reactions. Among these response functions, energy deposition coefficients and damage functions (atomic displacement constants) can be generated from the basic data given in ENDF/B.

The multigroup cross section production code SUPERTOG is widely used as a standard process code for use in the  $S_n$ -type transport code. In order to increase the utility of the code, we add the capability to produce energy deposition coefficients and atomic displacement constants. Both these constants represent the effect of the kinetic energy of neutrons transferring to medium atoms and, therefore, can be generated in almost the same calculation flow. The formulation for the displacement cross sections depends mainly on Doran's work.<sup>3)</sup>

In addition, some optional functions are added to the code. One is the option for calculating the Legendre coefficients from tabular data given in ENDF/B-4 libraries for the angular distribution of secondary neutrons in elastic scattering. The other is the generation of inelastic scattering matrices in the continuum excited level region on the basis of so-called the level density model.<sup>4)</sup> This formulation depends on the Yamakoshi work.<sup>5)</sup>

Sections 2 to 4 of this report present the mathematical models used for these calculations. Sections 5 and 6 provide input description and sample input/output, respectively.

## 2. Elastic Scattering Matrix

The original SUPERTOG code can compute the elastic scattering matrices only when the angular distribution of secondary neutrons is given in the form of Legendre coefficients (in ENDF/B file 4). In the SUPERTOG-JR code, when this angular distribution is given by tabular data, these data are converted to Legendre coefficients to compute the elastic scattering matrices. The conversion is performed with

$$f_l(E) = \int_{-1}^1 T(\mu, E) P_l(\mu) d\mu , \quad (1)$$

where  $f_l(E)$  is the Legendre coefficient for the  $l$ -th order and  $T(\mu, E)$  represent the tabular data given in ENDF/B file 4.

## 3. Inelastic Scattering Matrix

A new option is added for generating inelastic scattering matrices in the continuum excited level region, on the basis of so-called the level density mode,<sup>4)5)</sup> other than the built-in evaporation model.

The probability  $P(E, E-\epsilon)$  that an incident neutron of energy  $E$  remains in a residual nucleus of energy  $\epsilon$  through the formation of a compound nucleus is given by

$$P(E, E-\epsilon) = (E-\epsilon) \sigma_C(E-\epsilon) W(\epsilon) , \quad (2)$$

where  $\sigma_C(E-\epsilon)$  is the cross section for the formation of the compound nucleus and  $W(\epsilon)$  is the level density. The  $\sigma_C$  is given<sup>4)</sup> in a good approximation by:

$$\sigma_C(E) = [(0.76 + 2.2A^{-1/3}) + (2.12A^{-2/3} - 0.05)/E] R^2 \pi A^{2/3} , \quad (3)$$

where  $A$  is the mass of the residual nucleus and  $R = 1.5 \times 10^{-13} \times A^{1/3}$  (cm). Defining the parameters as  $U = \epsilon - \delta$  and  $U_C = 2.5 + 150/A$  where  $\delta$  is the pairing energy depending on the atomic number density  $N$  and  $Z$ , the level densities  $W_1$  and  $W_2$  are expressed respectively for the high and low energy regions as follows:

$$W_1(\epsilon) = \exp(2\sqrt{aU}) / (12\sqrt{2} \sigma a^{1/4} U^{5/4}) , \text{ for } U \geq U_C \quad (4)$$

$$W_2(\epsilon) = T_C \exp\{T_C(\epsilon - E_0)\} , \text{ for } U < U_C , \quad (5)$$

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$$W_2(\epsilon) = T_C \exp\{T_C(\epsilon - E_0)\} , \text{ for } U < U_C , \quad (5)$$

where

$$\sigma = 0.0888 A^{2/3} \sqrt{aU},$$

$$E_0 = U_C + \delta - \{\log(W_2(\epsilon)/T_C)\}/T_C,$$

$$T_C = a/U_C - 5\sqrt{4U_C},$$

and  $a$  is given theoretically by Newton or semi-empirically by Gilbert and Cameron as follows:

$$a = 0.154 (\bar{J}_Z + \bar{J}_N + 1) A^{1/3}, \quad (6)$$

where  $\bar{J}_Z$  and  $\bar{J}_N$  are respectively the average spin of protons and neutrons in the nucleus. Equation (6) can be rewritten as

$$a = A (0.00917S + 0.142), \quad (7)$$

where  $S$  represents the effect of shells of neutrons and protons.

#### 4. Atomic Displacement Constant and Heat Generation Coefficient

The atomic displacement constant and heat generation coefficient are generated by the new option LINK6=1 in SUPERTOG-JR in the same form as the activity cross sections. Both the constants represent the effect of the kinetic energy of neutrons transferring to medium atoms and, therefore, can be generated at the same time in the calculation flow. In the heat generation coefficient, all the kinetic energy transferred on the medium atom is calculated as the energy deposition. On the other hand, in the displacement cross section, only the energy contributing to displace medium atoms in a cascade initiated by primary knock-on atoms is calculated for obtaining the number of displaced atoms. The formulation depends mainly on Doran's work.<sup>3)</sup>

In RADHEAT version 2,<sup>6)</sup> the heat generation coefficient was obtained from the group constant and the group transfer matrices. In the present version, the heat generation coefficient as well as displacement cross section is generated directly from ENDF/B data.

The general expressions for the displacement cross section  $F(E)$  and the heat generation coefficient  $H(E)$  at the neutron energy  $E$  are respectively written as

$$F(E) = \sigma(E) \int_{E_d}^{T^{\max}} \left[ \frac{1}{\sigma} \frac{d\sigma(E, \phi)}{d\Omega} \right] \frac{d\Omega}{dT} (E, \phi) v(T) dT , \quad (8)$$

$$H(E) = \sigma(E) \int_0^{T^{\max}} \left[ \frac{1}{\sigma} \frac{d\sigma(E, \phi)}{d\Omega} \right] \frac{d\Omega}{dT} (E, \phi) T dT , \quad (9)$$

where  $\sigma(E)$  is an appropriate interaction cross section,  $d\Omega$  the element of solid angle,  $\phi$  the scattering angle in the center of mass (CM) system,  $v(T)$  the number of displacement per primary knock-on atom (PKA),  $T$  the kinetic energy of PKA in the laboratory system,  $T^{\max} = \gamma E$  the maximum possible PKA energy corresponding to a head-on collision ( $\phi=180^\circ$ ), and  $E_d$  the effective displacement threshold energy. The number of displacement  $v(T)$  is defined by

$$v(T) = \frac{L(\epsilon)}{\epsilon} \frac{T}{2E_d} , \quad (10)$$

where  $L(\epsilon)$  is the kinetic energy transferred to atoms of a cascade initiated by a PKA of dimensionless energy  $\epsilon$ , and it is given by

$$\begin{aligned}
 L(\varepsilon) &= \varepsilon / \{1 + k_L g(\varepsilon)\} , \\
 g(\varepsilon) &= \varepsilon + 0.40244 \varepsilon^{3/4} + 3.4008 \varepsilon^{1/6} , \\
 k_L &= 0.1334 Z^{2/3} A^{-1/2} , \\
 \varepsilon &= A_L T = 0.01151 T Z^{-7/3}
 \end{aligned} \tag{11}$$

where A and Z are respectively the atomic weight and number. A general expression relating T, E,  $\phi$ , and  $E_m$ , the energy of the scattered neutron in the CM system, is found from the conservation of momentum:

$$T = \eta_1 \eta_2 E + (\eta_1 / \eta_2) E_m - 2\eta_1 \sqrt{E E_m} \cos \phi , \tag{12}$$

where

$$\eta_1 = \frac{1.009}{1.009 + A} ,$$

$$\eta_2 = \frac{A}{1.009 + A} .$$

#### 4.1 Elastic Scattering

For elastic scattering, the energy conservation gives  $E_m = \eta_2^2 E$

$$T = \frac{1}{2} \gamma E (1 - \cos \phi) , \tag{13}$$

where  $\gamma = 4\eta_1 \eta_2$  and therefore

$$\frac{d\Omega}{dT} = -2\pi \frac{d\cos \phi}{dT} = \frac{4\pi}{\gamma E} = \frac{4\pi}{T_{\max}} . \tag{14}$$

The probability  $P(E, \mu)$  that a neutron of energy E is scattered at angle of  $\cos^{-1} \mu$  is written as

$$\begin{aligned}
 P(E, \mu) &= \frac{2\pi}{\sigma(E)} \frac{d\sigma}{d\Omega}(E, \mu) \\
 &= \sum_{\ell=0}^{NL} \frac{2\ell+1}{2} f_\ell(E) P_\ell(\mu) ,
 \end{aligned}$$

where  $f_\ell(E)$  is given in File 4 of ENDF/B. Equation (8) is now rewritten as

$$\begin{aligned}
 F(E) &= \frac{4\pi\sigma(E)}{T_{\max}^{\max}} \int_{E_d}^{T_{\max}} \left[ \frac{1}{\sigma} \frac{d\Omega}{dT} (E, T) \right] v(T) dT \\
 &= \frac{\gamma E \sigma(E)}{4E_d} \sum_{\ell=0}^{NL} \frac{2\ell+1}{2} f_\ell(E) \int_{-1}^{1-\xi} P_\ell(\mu) G(\mu, E) d\mu , \quad (15)
 \end{aligned}$$

where

$$G(\mu, E) = \frac{1-\mu}{1+k_L g(A_L T)}$$

$$\xi = \frac{2E_d}{T_{\max}} ,$$

and Eq. (9) becomes in the same manner as Eq. (8) as follows:

$$\begin{aligned}
 H(E) &= \sigma(E) \int_{-1}^1 P(E, \mu) T(E, \mu) d\mu \\
 &= \frac{\gamma E}{2} \sigma(E) [1 - f_1(E)] . \quad (16)
 \end{aligned}$$

#### 4.2 Inelastic Scattering

Inelastic scattering is treated by dividing it into the resolved part and the continuum part. The contribution from resolved levels to the displacement cross section is given by

$$F(E) = \sum_i F_i(E) , \quad (17)$$

where  $F_i(E)$  is the displacement cross section due to the  $i$ -th level. Energy conservation for an inelastic event yields

$$E_m = \eta_2 (\eta_2 E - Q_i) \quad (18)$$

where  $Q_i$  is the nuclear excitation energy for the  $i$ -th level and  $E_m$  is the energy of the scattered neutron. Substituting Eq. (18) into (12), we get

$$T_i = 0.5\gamma\{E - \mu\sqrt{E(E-Q_i/\eta_2)}\} - Q_i\eta_1 \quad (19)$$

$$\frac{d\Omega}{dT} = \frac{4\pi}{\gamma\sqrt{E(E-Q_i/\eta_2)}} . \quad (20)$$

Therefore it gives

$$F_i(E) = \frac{2\sigma_i(E)}{\gamma\sqrt{E(E-Q_1/\eta_2)}} \int_{T_i^-}^{T_i^+} P_i[E, \mu(E, T)] v(T) dT , \quad (21)$$

where  $\sigma_i(E)$  is the inelastic cross section for the  $i$ -th level, and  $T_i^+$  and  $T_i^-$  are respectively the upper and lower limits of  $T_i$ . Assuming the isotropic angular distribution, Eq. (21) is reduced to

$$\begin{aligned} F_i(E) &= \frac{\sigma_i}{2} \int_{-1}^1 v[T_i(E, \mu)] d\mu \\ &= \frac{1}{AE_d} \int_{-1}^1 \frac{T_i(E, \mu)}{1+k_L g[A_L T_i(E, \mu)]} d\mu \end{aligned} \quad (22)$$

Equation (9) becomes

$$\begin{aligned} H(E) &= \sum_i H_i(E) \\ &= \sum_i \sigma_i^{in}(E) \int_{-1}^1 \frac{1}{2} T_i(E, \mu) d\mu \\ &= \sum_i \left( \frac{\gamma}{2} E - Q_1 \eta_1 \right) \sigma_i^{in}(E) \end{aligned} \quad (23)$$

At high neutron energies, the inelastic scattering is described in an evaporation model characterized by an effective evaporation temperature  $\theta(E)$ . In this model, the energy  $E_m$  of the scattered neutron (CM system) is distributed as

$$f(E, E_m) = \frac{E_m}{I(E, \theta)} \exp\left(-\frac{E_m}{\theta}\right) , \quad (24)$$

where

$$I(E, \theta) = \theta^2 [1 - (1 + E_m^{\max}/\theta) \exp(-E_m^{\max}/\theta)] ,$$

$$E_m^{\max} = \eta_2(\eta_2 E - Q_1) .$$

The  $Q_1$  is the lowest energy level in the resolved region. The upper and lower limits of  $T$  are respectively written as

$$T^\pm = \eta_1 \eta_2 E + (\eta_1/\eta_2) E_m \pm 2\eta_1 \sqrt{E E_m} , \quad (25)$$

In addition, we have

$$\frac{d\Omega}{dT} = -2\pi \frac{d \cos \theta}{dT} = \frac{\pi}{n_1 \sqrt{EE_m}} . \quad (26)$$

Assuming the isotropic angular distribution, Eq. (8) is reduced to

$$\begin{aligned} F(E) &= \sigma^{in}(E) \int_0^{E_m^{\max}(E)} \int_{T-(E_m)}^{T+(E_m)} f(E, E_m) \frac{v(T)}{4n_1 \sqrt{EE_m}} dT dE_m \\ &= \frac{1}{4E_d} \sigma^{in}(E) \frac{1}{I(E, \theta)} \int_0^{E_m^{\max}(E)} \int_{-1}^1 E_m \exp(-\frac{E_m}{\theta}) \frac{T(E, E_m, \mu)}{1+k_L g(A_L T)} d\mu dE_m \\ &= \frac{1}{4E_d} \sigma^{in}(E) \frac{n_2^2}{I(E, \theta)} \int_{E_o}^E dE' \int_{-1}^1 d\mu E_m \exp(-\frac{E_m}{\theta}) \frac{T(E, E_m, \mu)}{1+k_L g(A_L T)} \end{aligned} \quad (27)$$

where in the last line  $E_m = n_2(n_2 E' - Q_1)$  and  $E_o = n_2/Q_1$ .

Equation (9) gives, in the same manner as shown above,

$$\begin{aligned} H(E) &= \sigma^{in}(E) \int_0^{E_m^{\max}} f(E, E_m) (n_1 n_2 E + \frac{n_1}{n_2} E_m) dE_m \\ &= \sigma^{in}(E) \{ n_1 n_2 E + \frac{n_1}{n_2} 2\theta \frac{1 - \exp[-\frac{E_m^{\max}}{\theta} (1 + \frac{E_m^{\max}}{\theta} + \frac{1}{2} (\frac{E_m^{\max}}{\theta})^2)]}{1 + \exp[-\frac{E_m^{\max}}{\theta} (1 + \frac{E_m^{\max}}{\theta})]} \} \end{aligned} \quad (28)$$

In the present program, when the inelastic scattering in the continuum part is not treated in the evaporation model, the displacement cross section and the heat generation coefficient are not calculated.

#### 4.3 ( $n, 2n$ ) Reaction

In this program the so-called 1-neutron model is used. This model differs from the evaporation model only in that  $E_m^{\max}$  is determined by Eq. (18) with  $Q_1$  replaced by the ( $n, 2n$ ) threshold energy. Equation (12) can therefore be expressed as

$$T = \frac{A}{A-1} \frac{n_1}{n_2} E_m + \frac{A-1}{A} \bar{T}_1 - 2(\frac{n_1}{n_2})^{1/2} (\bar{T} E_m')^{1/2} \mu \quad (29)$$

where  $\bar{T}_1 = \eta_1 \eta_2 E + (\eta_1 / \eta_2) E_m'$  is the mean recoil energy after the emission of the first neutron and  $E_m'$  is the energy of the second neutron. Assuming  $E_m = E_m'$ , it becomes

$$T = \frac{A-1}{(A+1)^2} E + \left( \frac{1}{A-1} + \frac{A-1}{A^2} \right) E_m - \frac{2}{A} [E_m \left( \frac{AE}{(A+1)^2} + \frac{E_m}{A} \right)]^{1/2} \mu. \quad (30)$$

The  $F(E)$  and  $H(E)$  are now obtained in the same manner as for the case of the evaporation model.

#### 4.4 $(n, \gamma)$ and $(n, \text{charged particle})$ Reactions

For the  $(n, \gamma)$  reaction, the recoil energy is given for the residual nucleus due to the neutron capture and the emission of gamma rays:

$$T = \frac{E}{A+1} + \frac{1}{2} \frac{[Q+AE/(A+1)]^2}{M_{n-\gamma}}, \quad (31)$$

where  $Q$  is the mass difference between the original nucleus and residual, and  $M_{n-\gamma}$  the mass of residual nucleus. The  $Q$  is given by

$$\begin{aligned} Q &= (M + M_n - M_{n-\gamma}) c^2 \\ &= (M + M_n - M_{n-\gamma}) \times 931.478 \text{ MeV}, \end{aligned} \quad (32)$$

$$M_n = 939.550/931.487 \text{ (neutron mass).}$$

Equation (8) now becomes

$$\begin{aligned} F(E) &= \sigma_{n,\gamma}(E) v(T) \\ &= \sigma_{n,\gamma}(E) \frac{1}{1+k_L g(A_L T)} \frac{T}{2E_d}. \end{aligned} \quad (33)$$

Equation (9) gives

$$H(E) = \sigma_{n,\gamma}(E) T. \quad (34)$$

For the  $(n, p)$  and  $(n, \alpha)$  reactions, the recoil energies are respectively given, in the same manner as described above, in the following forms:

$$T_{n,p} = E + (M + M_n - M_{n-p} - M_p) c^2 , \quad (35)$$

$$T_{n,\alpha} = E + (M + M_n - M_{n-\alpha} - M_\alpha) c^2 , \quad (36)$$

$M_p = 938.256/931.478$  (proton mass),

$M_\alpha = 4.0026032$  (alpha particle mass).

#### 4.5 Fission Reaction

Only the heat generation coefficient is generated as to the fission reaction. The energy released by the fission reaction is shown in Table 1. The kinetic energies of the fission fragments and  $\beta$ -particles are assumed to deposit at the fission point. Taking into account also the recoil energies due to the incident and emitted neutrons and gamma rays,  $H(E)$  is approximately given by

$$H(E) = \sigma_f(E) [h_f + h_\beta + \frac{E}{A+1} + \frac{1}{A_{F.P.}} \int dE' S_E(E') n(E') E' + \frac{h\gamma^2}{2M_{F.P.} c^2}] \quad (37)$$

where  $A_{F.P.}$  and  $M_{F.P.}$  are respectively the sums of the atomic numbers and masses of the two fission fragments, and  $S_E(E')$  and  $n(E')$  are respectively the fission spectrum and the emitted number of neutrons with energies of  $E'$ .

Table 1 Energy release from fission of  $^{235}\text{U}$ <sup>(7)</sup>

$h_f$	Light fragment Heavy fragment	$99.8 \pm 1$ MeV $68.4 \pm 0.7$
$h_\beta$	$\beta$ -decay of F.P.	7.8
Fission neutrons		4.8
$h\gamma$	Prompt gamma rays Delayed gamma rays	7.5, 8.518 <sup>(8)</sup> 6.8, 6.650 <sup>(8)</sup>

#### 4.6 Method of Integrals and Group Averages

The integral with respect to  $\mu$  to obtain  $F(E)$  is performed with the Gauss - Legendre method. The number of integral points is an input for IMUNO (in 6\$ array). To calculate the group averaged values  $\bar{F}(g)$  and  $\bar{H}(g)$ ,  $F(E)$  and  $H(E)$  are evaluated at NEPONT points (an input value

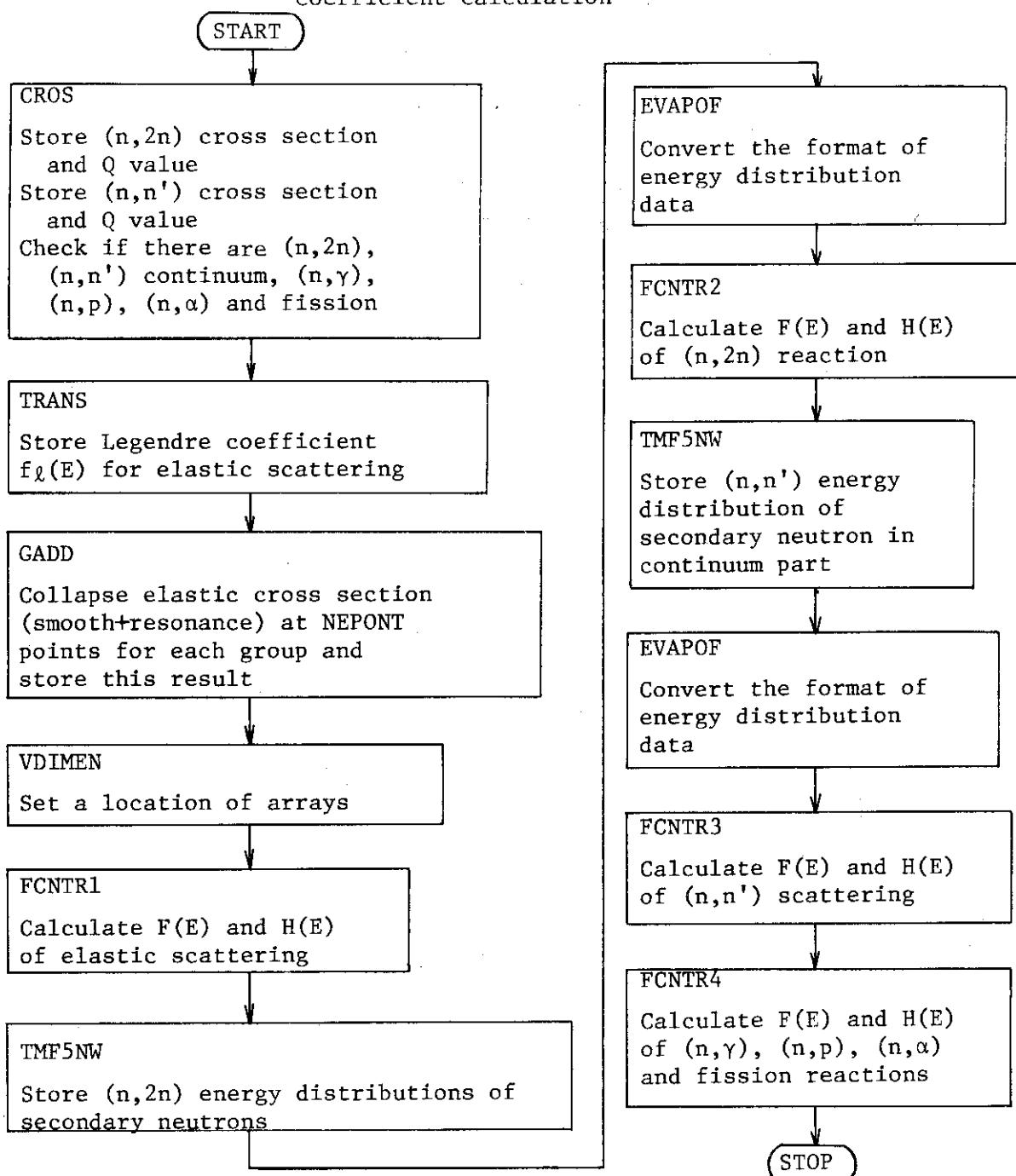
in 6\$ array) for each group. These values are averaged with the following equations:

$$\bar{F}(g) = \frac{\int_{E_g}^{E_{g+1}} W(E) F(E) dE}{\int_{E_g}^{E_{g+1}} W(E) dE}, \quad (38)$$

$$\bar{H}(g) = \frac{\int_{E_g}^{E_{g+1}} W(E) H(E) dE}{\int_{E_g}^{E_{g+1}} W(E) dE},$$

where  $W(E)$  is the weighting function. The flow diagram of the calculation of  $F(E)$  and  $H(E)$  is shown in Fig. 1.

Fig. 1 General flow chart of the displacement cross section and heat generation coefficient calculation



## 5. Input Description

Card No.1 (4I5, 4E10.0)

<u>Item</u>	<u>Cols.</u>	<u>Name</u>	
1	1-5	INALL	0 = only card number 1 and 4 are read. 1 = all input cards are read.
2	6-10	MATNO	ENDF/B tape material number.
3	11-15	LORDER	Order of $P_\ell$ for elastic scattering.
4	16-20	IREW	0 = no effect 1 = ENDF/B tape is rewound (IREW=1 for first material)
5	21-30	SIGP	Potential scattering cross section per resonance atom: $\text{SIGP} = \left( \frac{\sum p}{N} - 4\pi R^2 \right),$ where $\sum p$ is the mixture macroscopic potential cross section, N is the resonance isotope number density, and $4\pi R^2$ is the resonance isotope potential scattering (SIGP=10 <sup>8</sup> for infinite dilution).
6	31-40	AJIN	Input value of J for unresolved resonance calculation.
7	41-50	RFACT	r-factor (for GAM update)
8	51-60	SFACT	s-factor (for GAM update)

Card No.2 (10I5, E10.0)

1	1-5	IDTAP	ENDF/B tape identification number.
2	6-10	MODE	1 = ENDF/B tape is in binary mode 2 = ENDF/B tape is in BCD mode.
3	11-15	MCODE	1 = multigroup code is GAM-I (LORDER=1). 2 = multigroup code is GAM-II.
4	16-20	MAXG	Number of energy groups.

<u>Item</u>	<u>Cols.</u>	<u>Name</u>	
5	21-25	IEU	1 = GAM-I 68 group structure. 2 = GAM-II 99 group structure. 3 = input energy group structure. 4 = input lethargy group structure.
6	26-30	IW	1 = weighting function is 1/E. 2 = weighting function is 1.0. 3 = weighting function is input 4 = weighting function is 1/E jointed with a fission spectrum. A joint energy is given by EEJOIN of this card. 5 = analytic 1/E. 6 = weighting function is $1/(E \cdot \Sigma_t)$ (This option is not used for a resonance material).
7	31-35	ISPEC	0 = cross section averaging calculation. 1 = spectrum calculation.
8	36-40	IRES	Option for resolved resonance data. 0 = only the low energy resolved resonance data are added to the smooth cross section. 1 = all resolved resonance data are added to the smooth cross section as infinite dilution cross sections. 2 = GAM-II output, of which the $\ell=0$ resonances are transferred and the $\ell=1$ resonances are added to the smooth background.
9	41-45	IPUN	0 = no punched output. 1 = output in the GAM format. 2 = output in the ANISN format. 3 = output in both the GAM and ANISN format.
10	46-50	N040	Treatment of elastic scattering matrix for thermal group 0 = no effect 1 = (MAXG→MAXG+1) is added to (MAXG→MAXG). (The SUPERTOG assumes that the group (MAXG+1) is the thermal group, but this option makes the group MAXG into the thermal group.)

<u>Item</u>	<u>Cols.</u>	<u>Name</u>
-------------	--------------	-------------

11	51-61	EEJOIN Energy in units of eV at which the fission spectrum is jointed with 1/E. If the energy does not given, this value is automatically set to 6.74 keV.
----	-------	--

Card No. 3 (6I5)

Options desired for the SUPERTOG run.

1	1-5	LINK1      0 = no      } resonance calculation 1 = yes     }
2	6-10	LINK2      0 = no      } smooth cross sections 1 = yes     }
3	11-15	LINK3      0 = no      } elastic scattering matrices 1 = yes     }
4	16-20	LINK4      Inelastic scattering matrix. 0 = not calculate 1 = by ENDF/B data (same as original) 2 = continuum part is the Gilbert-Cameron's level density model. 3 = continuum part is the Newton's level density model.
5	21-25	LINK5      0 = no      } (n,2n) scattering matrix 1 = yes     }
6	26-30	LINK6      0 = no      } displacement cross sections and 1 = yes     } heat generation coefficients.

Card(S) No.4

This card is necessary only if LINK6=1. These data are used to calculate displacement cross sections and heat generation coefficients.

Card 4.1 (3I5)

1	1-5	IMUNO      Number of the angular mesh points in integral calculation, normally 20.
2	6-10	NEPONT      Number of the energy mesh points for one group in integral calculation, normally 10.

<u>Item</u>	<u>Cols.</u>	<u>Name</u>	
3	11-15	NPRINT	0 = no effect 1 = detailed print for fine groups

Card 4.2 (6E10.0)

1	1-10	ED	Effective displacement energy (eV).
2	11-20	AM	Atomic weight of the nucleus on ground state.
3	21-30	AMNG	Atomic weight of the residual nucleus for (n, $\gamma$ ) reaction.
4	31-40	AMNP	Atomic weight of the residual nucleus for (n,p) reaction.
5	41-50	AMNA	Atomic weight of the residual nucleus for (n, $\alpha$ ) reaction.
6	51-60	HFB	Kinetic energy of the fission fragment (eV).

The unit of the atomic weight is carbon-unit. If the recoil energy due to the mass difference can be neglected, set AMNG=AMNP=AMNA=0.0.

Card(s) No.5

This is actually a card set necessary only if IW=3. The set consists of the desired weighting function as tabulated values and the interpolation tables defining the interpolation scheme to be used with the tabulated values. The weighting function must be given in ascending order of energy. The format of the card set is a standard ENDF/B TAB 1 record.

Card 5.1 (44X,2I11)

1	45-55	N1	Number of interpolation ranges.
2	56-66	N2	Number of weighting function points.

Card 5.2 - .... (6I11)

1	1-11	NBT(1)	Last point number in 1st interpolation range.
2	12-22	JNT(1)	Interpolation scheme for 1st range.

<u>Item</u>	<u>Cols.</u>	<u>Name</u>	
3	23-33	NBT(2)	Last point number in 2nd interpolation range.
4	34-44	JNT(2)	Interpolation scheme for 2nd range.
⋮			
etc.			
2*N1-1		NBT(N1)	Last point number in N1 interpolation range.
2*N1		JNG(N1)	Interpolation scheme for the N1 range.

Card 5.3 - ... (5E11.4)

1	1-11	BLOCK3(1)	First energy point (< lowest energy in group structure).
2	12-22	BLOCK4(1)	Weight at this energy.
⋮			
etc. using N2/3 cards			
2*N2-1		BLOCK3(N2)	Last energy point (> highest energy in group structure).
2*N2		BLOCK4(N2)	Weight at this energy.

Card(s) No.6

This is actually a card set necessary only if IEU=3 or 4. The set specifies the desired group structure. If IEU=3, the set gives the energy boundaries of the structure given in ascending order of energy. If IEU=4, the set gives the lethargy boundaries of the structure given in descending order of lethargy.

Card 6.1 (6E11.4)

1	1-11	XX(1)	Group boundary 1.
2	12-22	XX(2)	Group boundary 2.
⋮			
etc. using (MAXG+1)/6 cards			
⋮			

<u>Item</u>	<u>Cols.</u>	<u>Name</u>
MAXG	XX(MAXG)	Group boundary MAXG.
MAXG1	XX(MAXG+1)	Group boundary MAXG+1.

If IEU=3, XX is denoted as EGRP; if IEU=4, XX is denoted as UGRP.

#### Card 7 (4E12.5)

This card gives  $\sigma_A$ ,  $\mu\sigma_F$ ,  $\sigma_t$  and  $\sigma_{g \rightarrow g}$  for the thermal group. The card is required only if IPUN (Card 2) = 2 or 3 and NO40 (Card 2) = 0.

1	1-12	SIGA	$\sigma_A$
2	13-24	NU-SIGF	$\nu\sigma_F$
3	25-36	SIGT	$\sigma_t$
4	37-48	SIG-GG	$\sigma_{g \rightarrow g}$

## 6. Sample Input and Output

A sample problem is presented for iron, ENDF/B-IV Mat. No. 1192 in a 26-group structure. The weighting function was a 1/E spectrum jointed with a fission spectrum. Resolved and unresolved resonance data were used to generate contributions to the smooth cross sections. The  $P_3$  elastic scattering transfer coefficients, inelastic and  $(n,2n)$  scattering matrices, atomic displacement cross sections and energy deposition coefficients were generated in ANISN format.

The input data for the sample problem and an abbreviated list of the output are given in the Appendix C.

## Acknowledgement

The authors would like to express sincere thanks to Dr. T. Asaoka for planning to expand the capability of the present code for the generation of the atomic displacement constants.

## References

- 1) Wright R. W., et al.: "SUPERTOG-3," ORNL-TM-2679, (1969).
- 2) Lindhard J., et al.: Mat. Fys. Medd. Dan. Vid. Selsk., 33, No. 10 (1963).
- 3) Doran D. G.: Nucl. Sci. Eng., 49, 130 (1972).
- 4) For example, Muther S. C., et al.: Phys. Rev. 186, 1038 (1969). Dostrovsky I., et al.: Phys. Rev. 116, 683 (1959).
- 5) Yamakoshi T.: Private communication.
- 6) Miyasaka S., et al.: "RADHEAT, Code System for the Radiation-Heating Analysis of a Nuclear Reactor", (in Japanese) JAERI-M 5794 (1974).
- 7) Keppin G. R.: "Physics of Nuclear Kinetics", Addison-Wesley (1965).
- 8) Summary Report on the Physics Problems of Reactor Shielding, ENEA/IAEA, Shielding Specialist Meeting, Paris (1970).

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- 3) Doran D. G.: Nucl. Sci. Eng., 49, 130 (1972).
- 4) For example, Muther S. C., et al.: Phys. Rev. 186, 1038 (1969).  
Dostrovsky I., et al.: Phys. Rev. 116, 683 (1959).
- 5) Yamakoshi T.: Private communication.
- 6) Miyasaka S., et al.: "RADHEAT, Code System for the Radiation-Heating Analysis of a Nuclear Reactor", (in Japanese) JAERI-M 5794 (1974).
- 7) Keppin G. R.: "Physics of Nuclear Kinetics", Addison-Wesley (1965).
- 8) Summary Report on the Physics Problems of Reactor Shielding,  
ENEA/IAEA, Shielding Specialist Meeting, Paris (1970).

## Appendix A Descriptions of Subroutines Added to SUPERTOG

## A.1 Displacement cross section and heat generation coefficient

## A.1.1 Subroutine VDIMEN

VDIMEN sets the locations for each array in the variable dimension. If the last location exceeds the maximum size, error message is written and the execution is terminated.

called from: ETOG

definition of variables;

LADR	:	location of the group averaged value $\bar{R}(g)$
LADF	:	location of the group averaged value $\bar{F}(t)$
LADH	:	location of the group averaged value $\bar{H}(g)$
LADE	:	location of the fine group energy structure
LADY	:	location of $F(E)$ for fine group
LADHH	:	location of $R(E)$ for fine group
LADXE	:	location of cross section
LADXL	:	location of the energy at which Legendre coefficients are given
LADYL	:	location of Legendre coefficients
LAD1	:	location of zeros of Legendre polynomial $P_n(\mu)$
LAD2	:	location of the weighting function in Gauss integration
LAD3	:	location of temporary area
LAD4	:	location of temporary area
LADTTA	:	location of the Q value
LLAST	:	last location

## A.1.2 Subroutine FCNTR1

FCNTR1 is a control program to calculate  $F(E)$  and  $H(E)$  due to the elastic scattering. Total elastic scattering cross sections of fine groups, one group of which is divided into NEPONT points, are calculated in the subroutine STELAS called from subroutine GADD, and stored in file 80. The Legendre coefficient  $f_\ell(E)$  is given by the tabulated function in ENDF/B, File 4, MT=2, and these coefficients are stored in file 81 in the subroutine TRANS. The  $F(E)$  and  $R(E)$  are calculated at NEPONT points for each group and are averaged by using the weighting function.

called from: ETOG

subroutine called: ELAS00, GRPAVG, OUT000, OUT001 OUT002

definition of variables;

RBAR : group averaged value of  $R(E)=F(E)/\sigma(E)$

FBAR : group averaged value of  $F(E)$

HBAR : group averaged value of  $H(E)$

GKL : KL

AL : AL

ETA1 :  $\eta_1$

ETA2 :  $\eta_2$

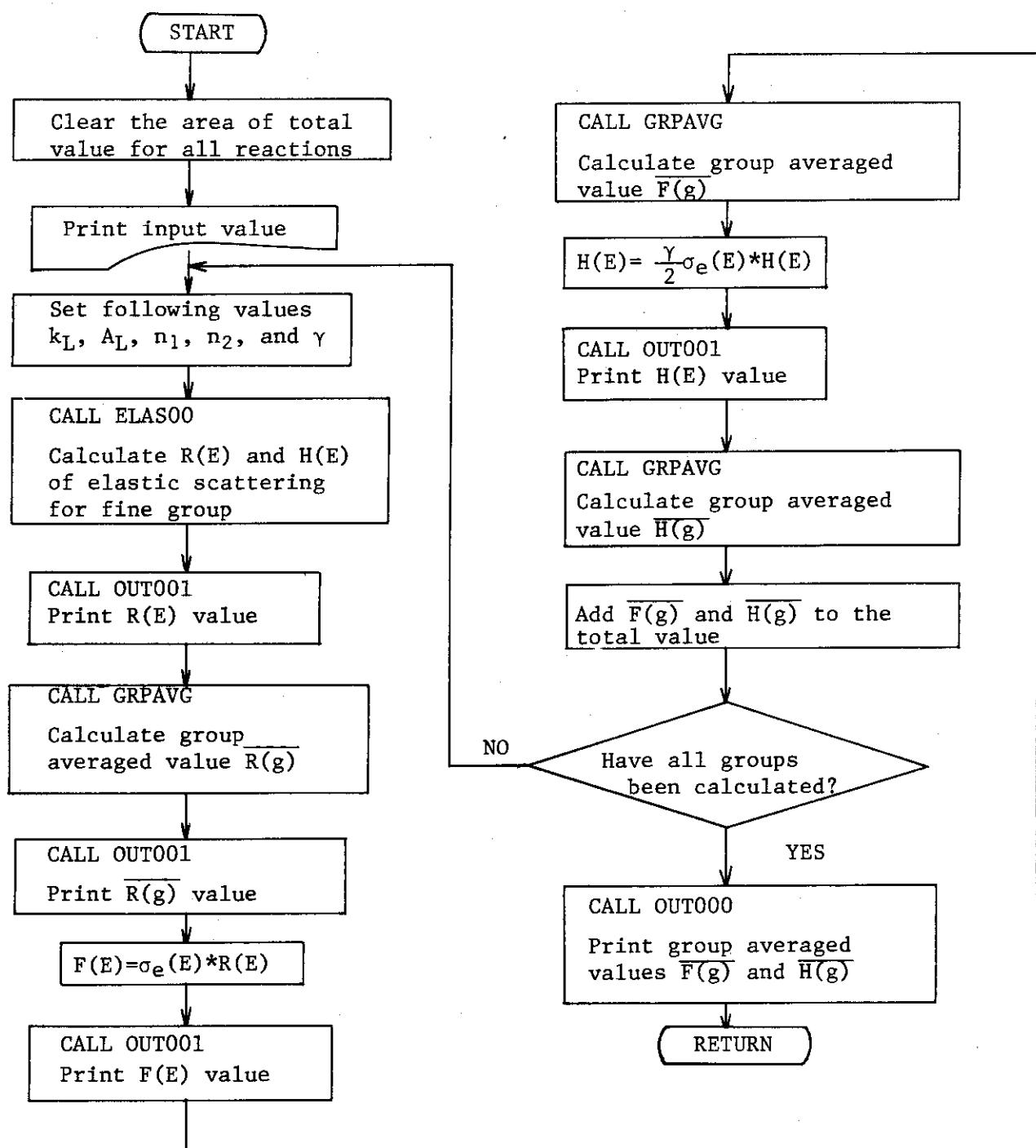
GAMMA :  $\gamma$

XELAS : total elastic scattering cross section

YYYY :  $F(E)$  for fine group

HHHH :  $H(E)$  for fine group

## Subroutine FCNTR1



## A.1.3 Subroutine FCNTR2

FCNTR2 is a control program to calculate  $F(E)$  and  $H(E)$  due to the  $(n,2n)$  reaction. The total  $(n,2n)$  fine group cross sections are calculated in the subroutine SUBMAX called from ETOG, and stored in file 86. The energy distribution of secondary neutrons is stored in file 85 in the subroutine EVAPOF which is called from ETOG. When this energy distribution is not the evaporation spectrum (ENDF/B, File 5, LF=9), this subroutine is not called.

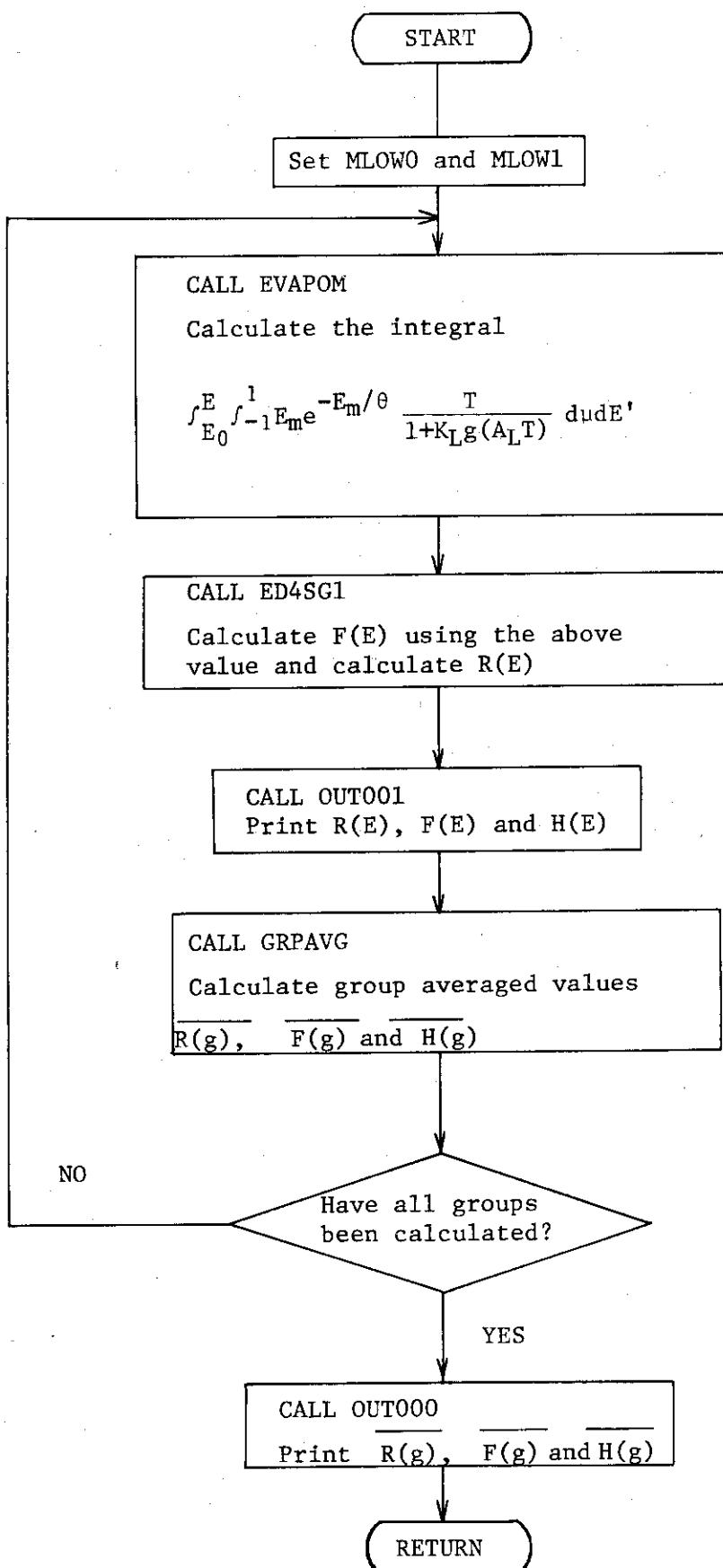
called from: ETOG

subroutine called: EVAPOM, ED4SG1, SAVENW, GRPAVG, OUT000,  
OUT001, OUT002

definition of variables;

RBAR	:	group averaged value of $R(E)=F(E)/\sigma(E)$
FBAR	:	group averaged value of $F(E)$
HBAR	:	group averaged value of $H(E)$
YYYY	:	$F(E)$ for fine group
HHHH	:	$H(E)$ for fine group
THETAE	:	effective evaporation temperature
EMNMN2, THRSH2	:	threshold energy of $(n,2n)$ reaction
E0	:	lower limit energy of integral variable in Eq. (27)
MLOW0	:	group number in which $E_0$ is located
MLOW1	:	lowest group number in which $(n,2n)$ reaction occurs

## Subroutine FCNTR2



### A.1.3 Subroutine FCNTR3

FCNTR3 is a control program to calculate F(E) and R(E) due to the inelastic scattering. The cross sections at the resolved and continuum region stored in file 04 by the subroutine CROS are collapsed to the fine group cross sections in subroutine INELAD. The cross sections for resolved levels are stored in file 82 with the direct access format, and those for the continuum part are stored in file 83. The F(E) and R(E) for resolved part are calculated for each resolved level. Energy distribution of secondary neutrons for continuum part is stored in file 81 by the subroutine EVAPOF which is called from the subroutine INELAS. When this energy distribution is not given by evaporation spectrum, the calculation for continuum part is not executed like the case of the (n,2n) reaction.

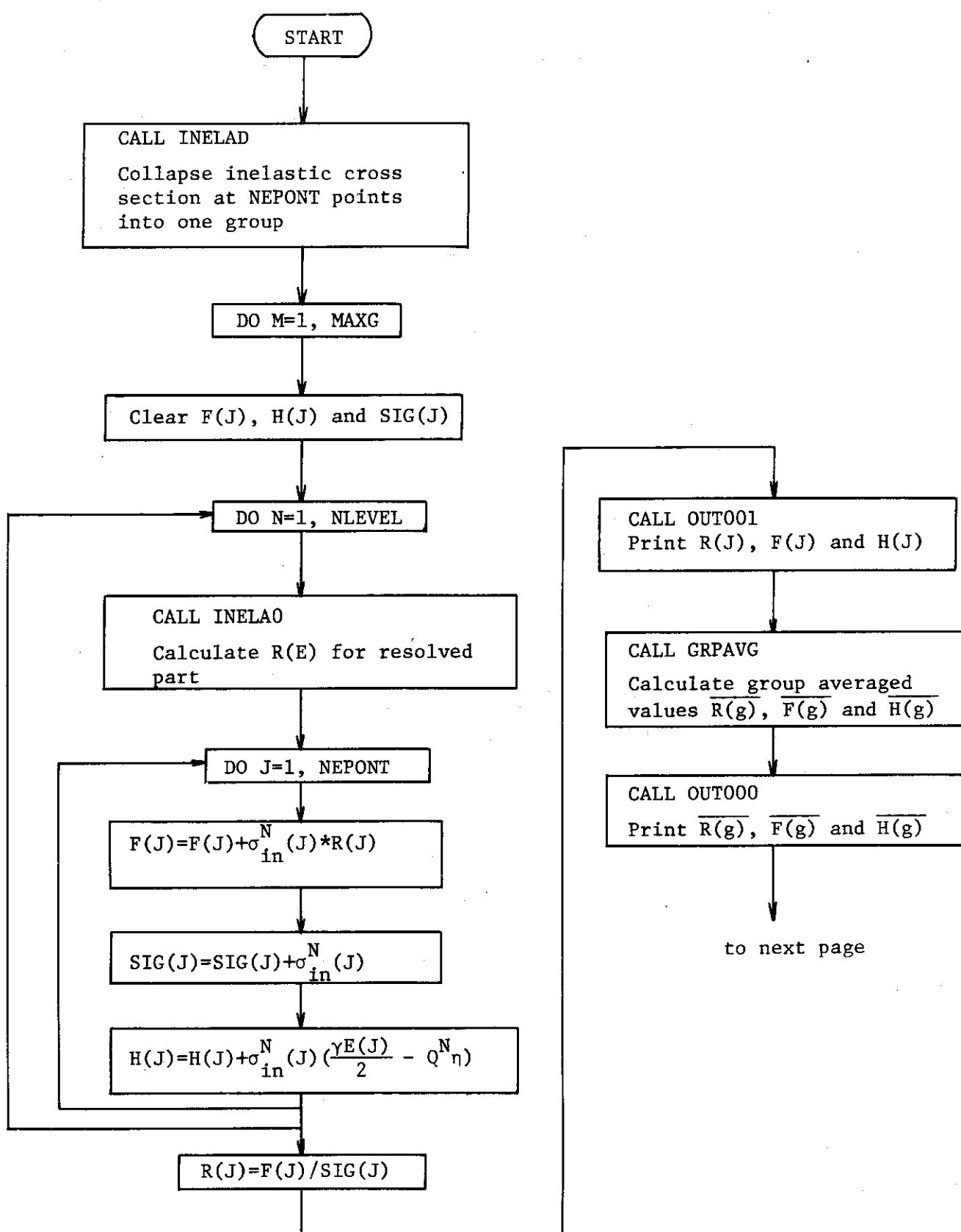
called from: INELAS

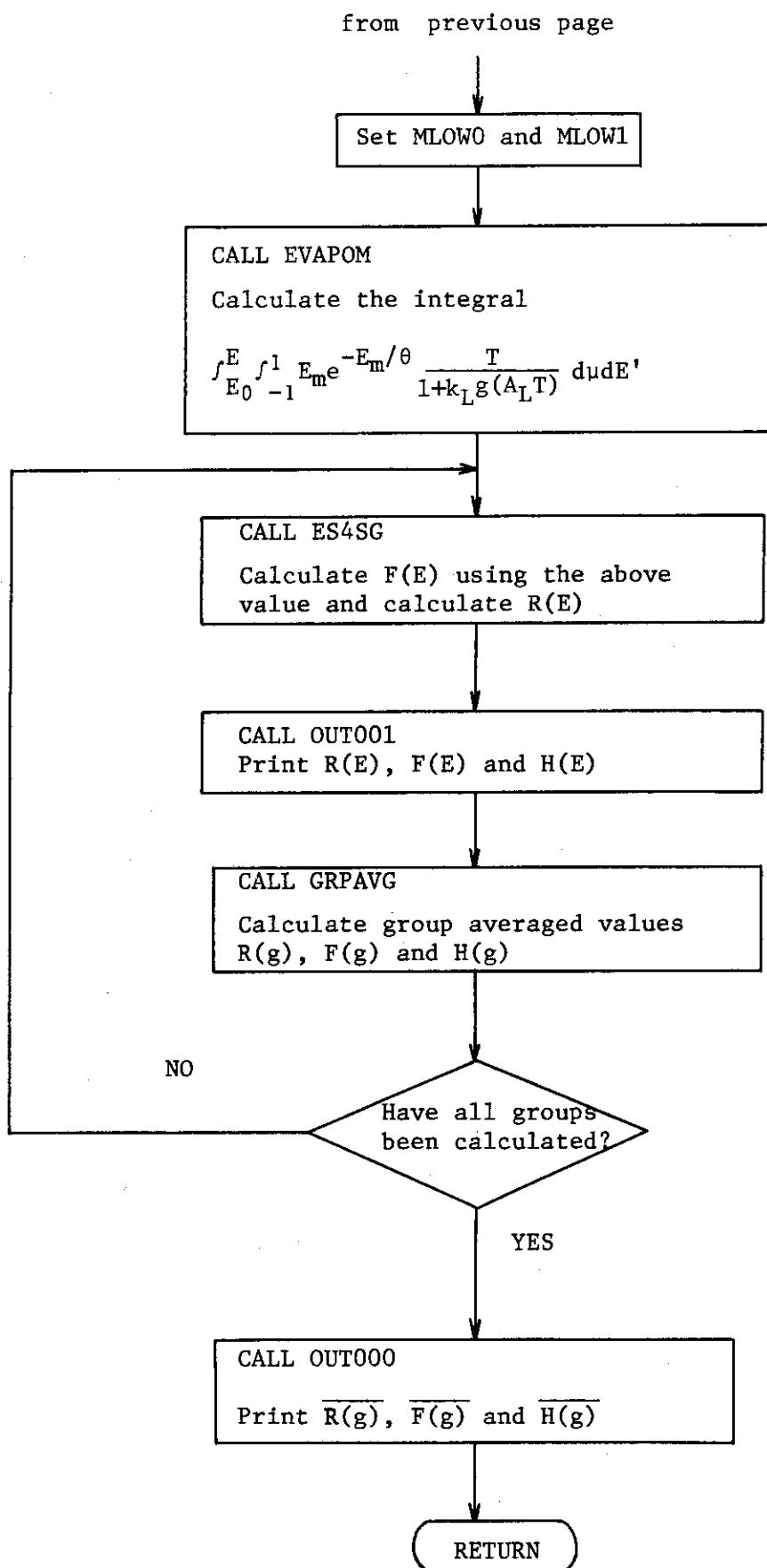
subroutine called: INELAD, INELAO, EVAPOM, ED4SG, GRPAVG,  
OUT000, OUT001, OUT002

definition of variables;

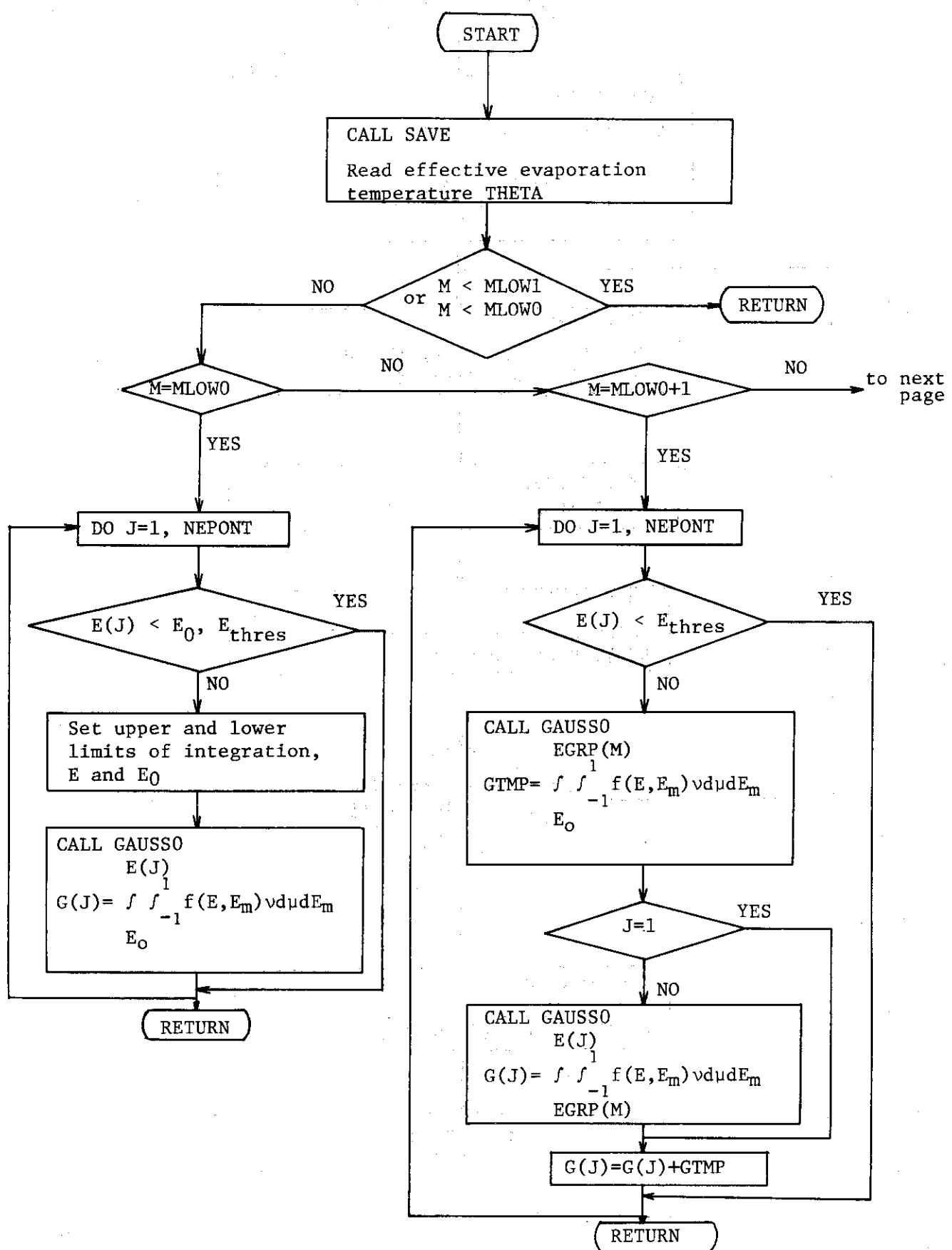
BRAR	:	group average value of R(E)
FBAR	:	group average value of F(E)
HBAR	:	group average value of H(E)
NLEVEL	:	number of resolved levels
THET3	:	energy for each resolved level
FE81	:	F(E) for fine group
SIGM81	:	total inelastic scattering cross section for resolved part
HE81	:	H(E) for fine group

## Subroutine FCNTR3

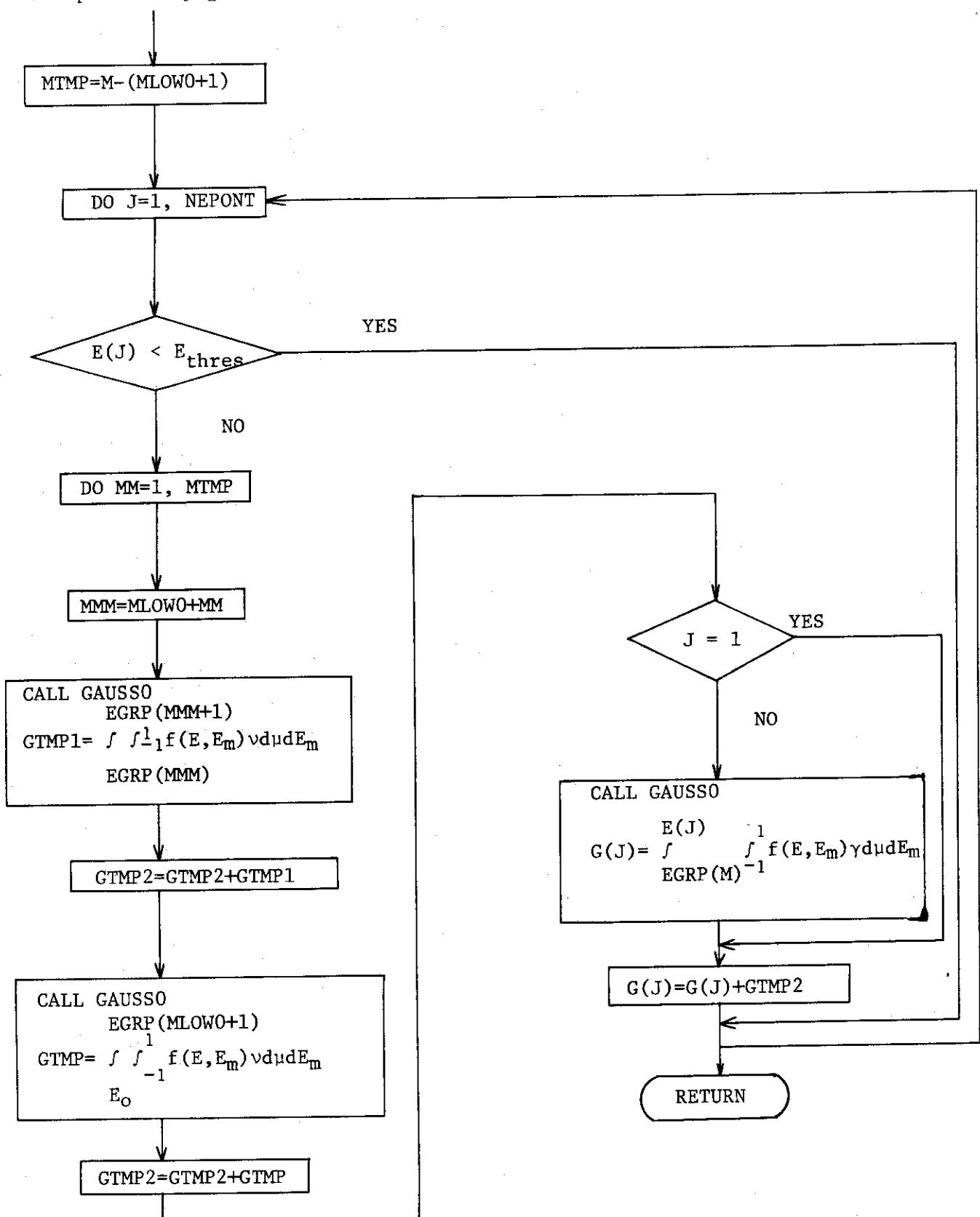




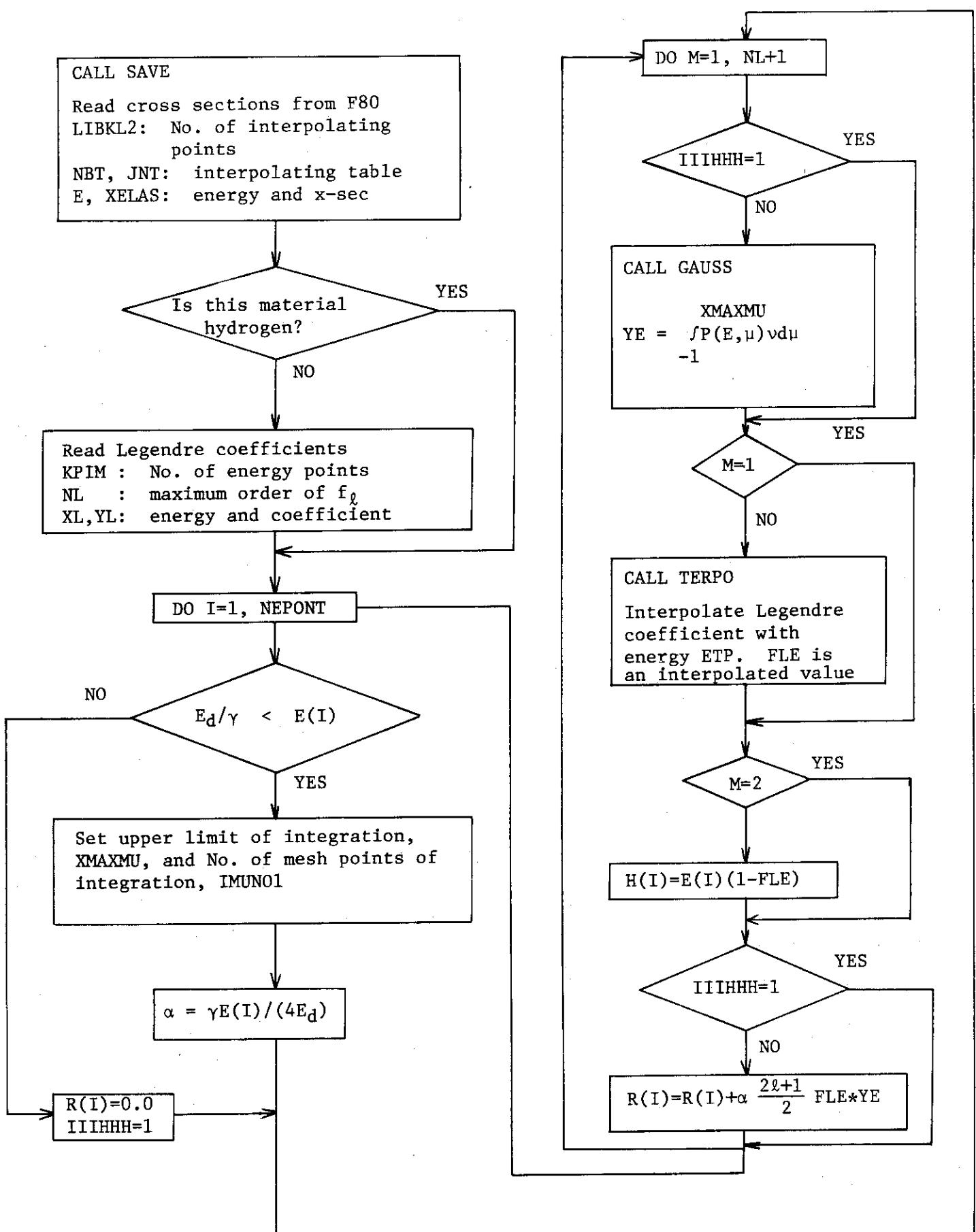
## A.1.4 Subroutine EVAPOM



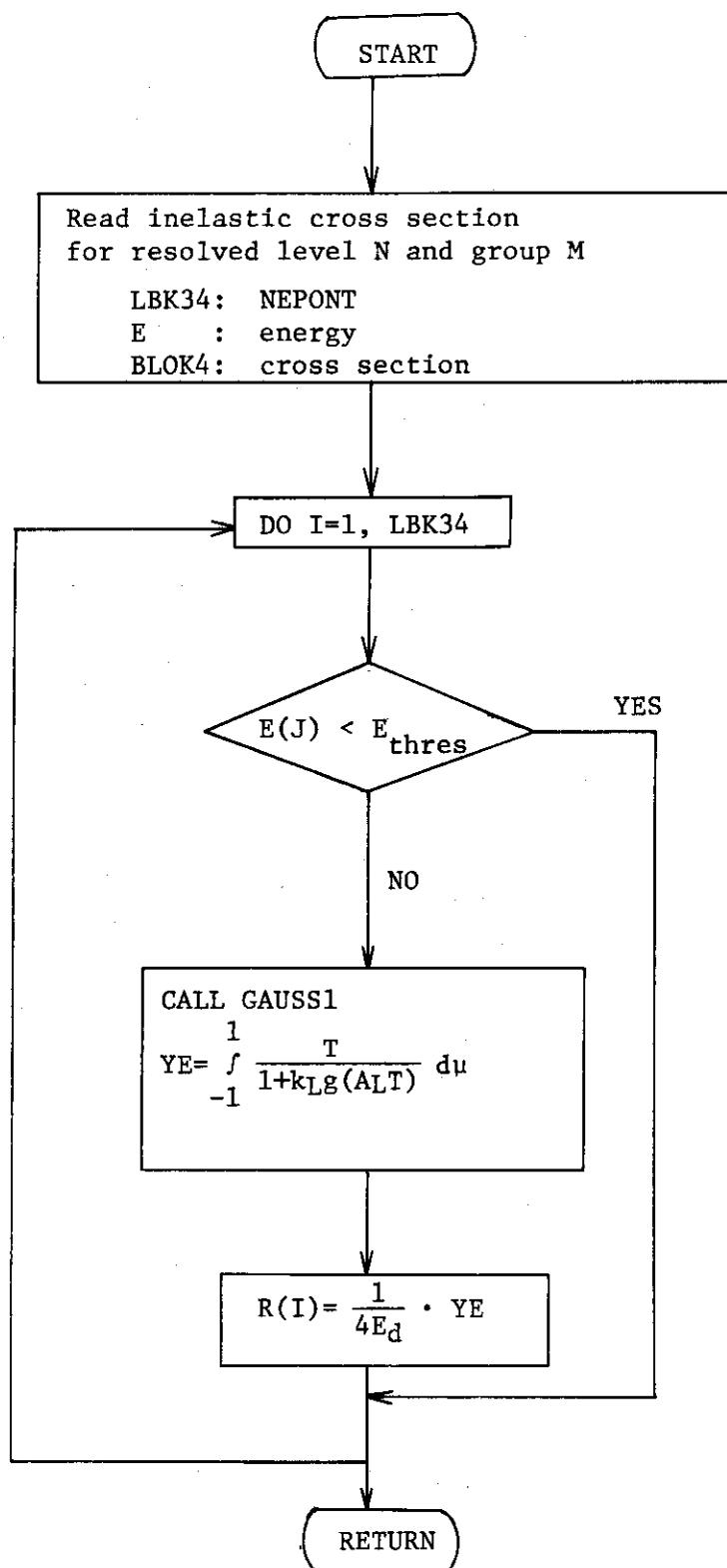
from previous page



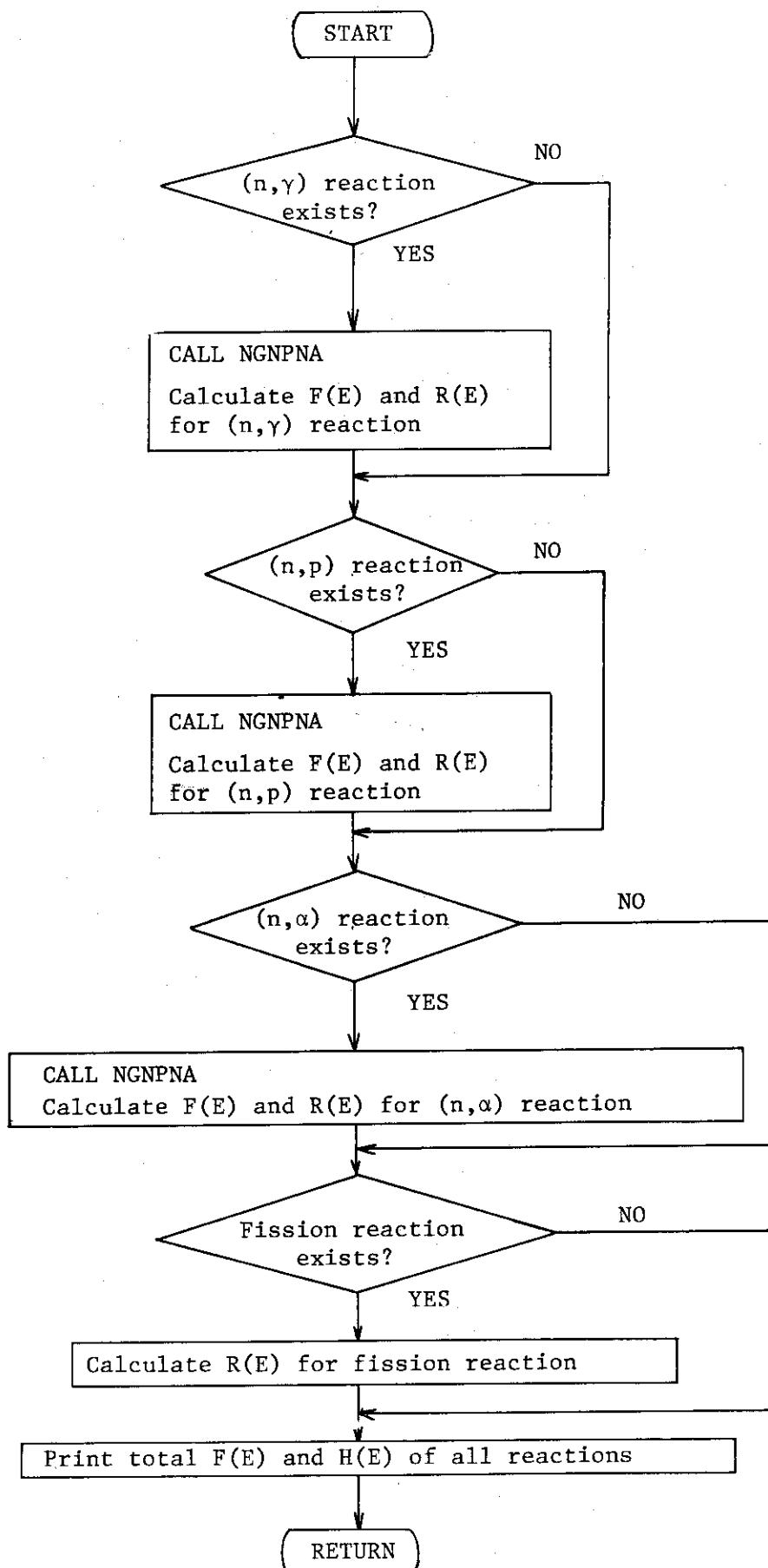
### A.1.5 Subroutine ELAS00



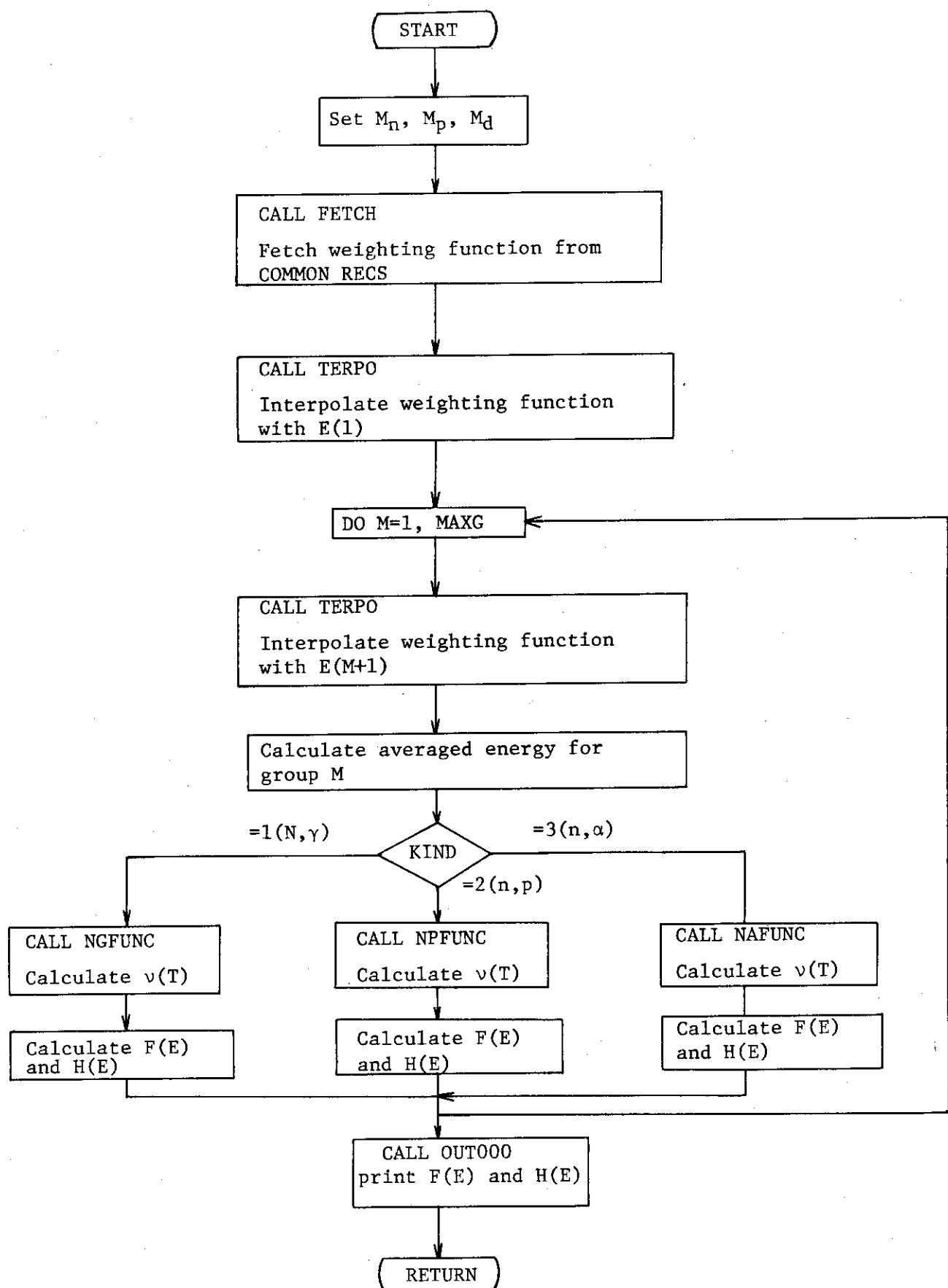
## A.1.6 Subroutine INELAO



## A.1.7 Subroutine FCNTR4



## A.1.8 Subroutine NGNPNA



## A.1.9 Other subroutines

## 1. GAUSS

called from: ELAS00

subroutine called: XWEIGO, GNUE, LEGDDN

calculate  $\int_a^b P_n(\mu) G(E, \mu) d\mu$  by Gauss-Legendre method.

## 2. XWEIGO

called from: GAUSS

obtain  $\mu_i$  ( $i=1, \dots, n$ ) satisfying  $P_n(\mu) = 0$  and its corresponding weights

## 3. GNUE

called from: GAUSS

calculate  $G = \frac{1-\mu}{1+k_L g(A_L T)}$ 

## 4. LEGDDN

called from: GAUSS

calculate the Legendre polynomial  $P_n(\mu)$ 

## 5. INELAD

called from: FCNTR3

subroutine called: SAVE, TERPO, DFILE

collapse inelastic scattering cross section for resolved and continuum part

## 6. GAUSS1

called from: INELAO

subroutine called: GNUE1

calculate  $\int_{-1}^1 G(E, \mu) d\mu$  by Gauss-integral method

## 7. GNUE1

called from: GAUSS1

calculate  $G = \frac{T}{1+k_L g(A_L T)}$

8. TMF5NW
 

called from: ETOG, INELAS  
   subroutine called: SAVE  
   store energy distribution of secondary neutrons
9. EVAPOF
 

called from: ETOG, INELAS  
   subroutine called: SAVE, SUBMAX  
   convert the format of energy distribution
10. GAUSSO
 

called from: EVAPOM  
   subroutine called: KWEIGO, GNUE2, GNUE3  
   calculate  $\int_{E_0}^E \int_{-1}^1 F \cdot G d\mu dE'$  by Gauss-integral method where F and G are shown at GNUE2 and GNUE3 in the below:
11. GNUE2
 

called from: GAUSSO  
   calculate  $F = \frac{T(E', \mu)}{1 + k_L g(A_L T)}$  for inelastic scattering
12. GNUE3
 

called from: GAUSSO  
   calculate  $G = E_m(E') \exp(-E_m(E')/\theta(E))$  for inelastic scattering
13. ED4SG
 

called from: FCNTR3  
   subroutine called: SAVE  
   calculate F(E) for inelastic scattering reaction in the continuum region using integrated values.
14. GNUE4
 

called from: GAUSSO  
   calculate  $F = \frac{T}{1 + k_L g(A_L T)}$  for (n, 2n) reaction
15. ED4SG1
 

called from: FCNTR2  
   subroutine called: SAVE  
   calculate F(E) for (n, 2n) reaction using integrated values.

## 16. N2NCRS

called from: CROS  
subroutine called: SAVE  
store (n,2n) corss section (MF=3, MT=16)

## 17. MGFUNC

called from: NGNPNA  
subroutine called: GALT  
calculate recoil energy T and v(T) for (n, $\gamma$ ) reaction

## 18. NPFUNC

called from: NGNPNA  
subroutine called: GALT  
calculate recoil energy T and v(T) for (n,p) reaction

## 19. NAFUNC

called from: NGNPNA  
subroutine called: GALT  
calculate recoil energy T and v(T) for (n, $\alpha$ ) reaction

## 20. GALT

called from: NGFUNC, NPFUNC, NAFUNC  
calculate v(T) for given T value

## 21. SUBMAX

called from: EVAPOF  
subroutine called: SAVE, TERPO  
interpolate any data into NEPONT mesh points for each group and  
store the results.

## 22. STELAS

called from: GADD  
subroutine called: TERPO, SAVE  
collapse elastic scattering cross section at NEPONT points for  
each group and store the results

## 23. GRPAVG

called from: FCNTR1, FCNTR2, FCNTR3

- subroutine called: GPAVNW  
set constants to calculate group averaged value
24. GPAVNW  
called from: GRPAVG  
subroutine called: STORE, ERR, GRATE, CRAV, COMB  
average fine group cross sections using weighting function
25. OUT000  
called from: FCNTR1, FCNTR2, FCNTR3, NGNPNA, FCNTR4  
print group averaged values  $\bar{R}_g$ ,  $\bar{F}_g$  and  $\bar{H}_g$
26. OUT001  
called from: FCNTR1, FCNTR2, FCNTR3, NGNPNA  
print fine group values R(E), F(E) and H(E)
27. OUT002  
called from: FCNTR1, FCNTR2, FCNTR3  
print title statement for each reaction type

#### A.2 Elastic scattering matrix

The subroutines concerned with elastic scattering matrix calculations are as follows:

1. TABLET2  
called from: TMF4  
read the angular distribution in the form of tabular data from ENDF/B file 4
2. PTOFL  
called from: TMF4  
subroutine called: PINTEG  
transfer the calculated Legendre coefficients to the common data area.
3. PINTEG, SIMPSN and LEGDD  
called from: PTOFL  
calculate the Legendre coefficients by the Simpson integral method

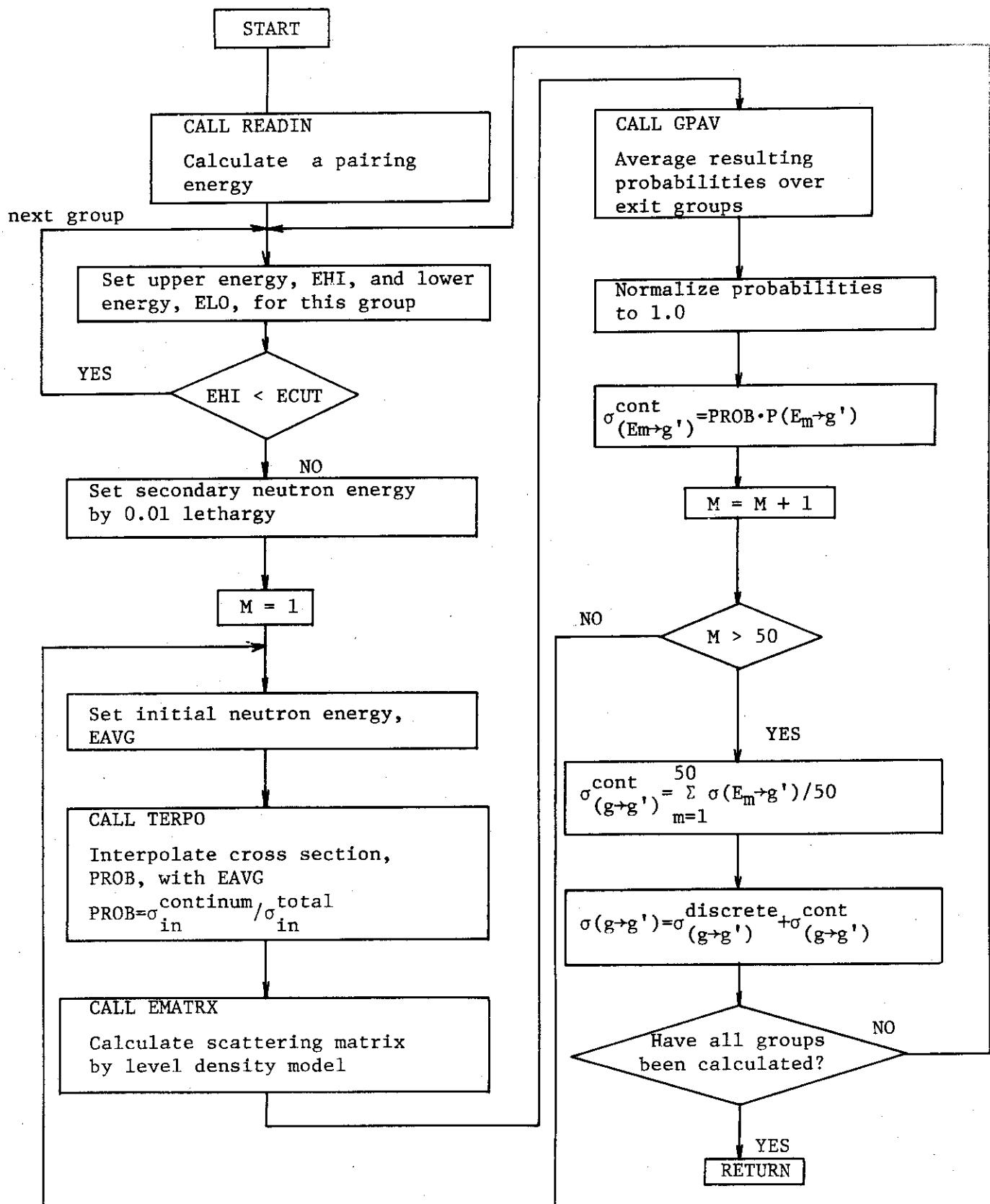
4. SUBNW4

called from: TRANS

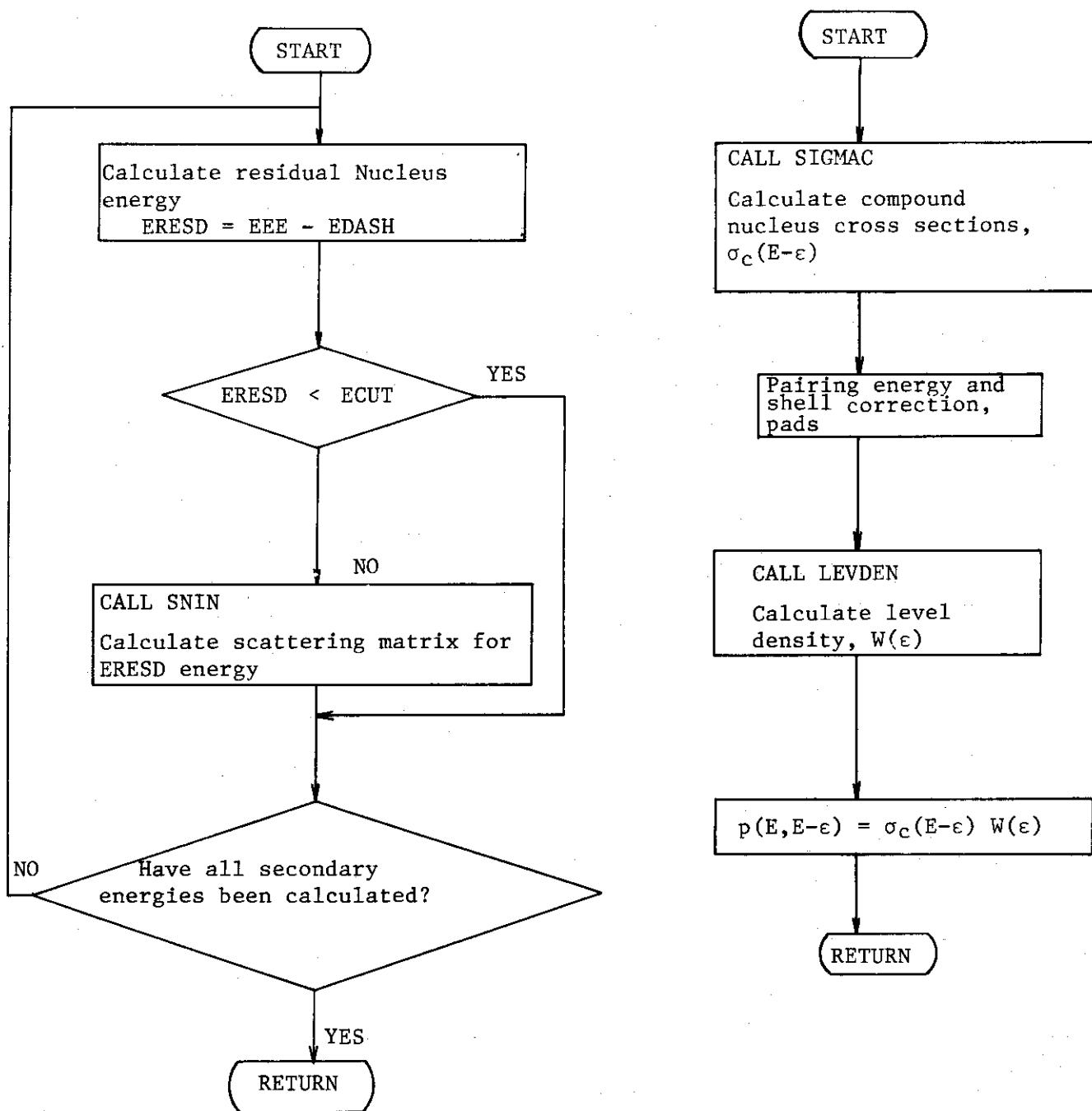
add  $\sigma_s$  (MAXG $\rightarrow$ MAXG+1) to  $\sigma_s$  (MAXG $\rightarrow$ MAXG) if input value N040 (4\$)  
is 1

## A.3 Inelastic scattering matrix

## A.3.1 Subroutine CONTUM



## A.3.2 Subroutines EMATRX and SNIN



A.3.3 Other subroutines

1. READIN

called from: CONTUM

subroutine called: HOSEI

calls HOSEI and print important information

2. LEDVEN

called from: SNIN

subroutine called: AAOAA1

calculate level density parameter by Newton or Gilbert-Cameron formula, and calculate level density  $W(\epsilon)$

3. AAOAA1

called from: LEVDEN

calculate level density parameter by Newton's equation

4. SIGMAC

called from: SNIN

calculate compound cross section in inverse process

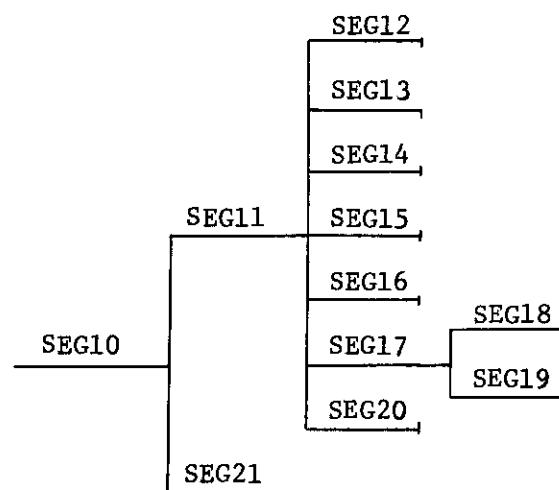
5. HOSEI

called from: READIN

calculate pairing energy and shell correction for neutrons and protons

## Appendix B Overlay Structure for SUPERTOG-JR

Segment		Subroutines				
SEG10	FTMAIN	DFILE				
SEG11	ETOG	TPOS	LIST	CONT	TAB1	TAB2
	SAVE	XTND	AVRG	FETCH	STORE	ERROR
	ERR	CRAV	GPAV	ADD	COMB	SUB
	MULT	DIV	TERP	TERP1	TERP2	LRIDS
	FPDS	IPDS	TERPO	COMBP	GRATE	ECSI
	DELETE	TRID	TMAT	HOLL	TMF3	TMF5
	OUT000	OUT001	OUT002	MISS	GRPAVG	GPAVNW
	XWEIGO	SAVENW	SUBMAX			
SEG12	TMF1 KERN	EU FISS	ZERO CHECK	ININ SKPFIL	GENT1	OUT1
SEG13	TMF2	RESS	MASH	VOGAM	TDEGK	
SEG14	RESR	RESU	XSRT	FJ	DLAG	INTER
SEG15	CROS	HSCAT	OUT3	OUT4	OUT6	N2NCRS
SEG16	TRANS	GUTS	GRID	BAST	GADD	TMF4
	RQW8	RQW9	LEGM	INTERP	SUBNW4	PTOFL
	PINTEG	SIMPSON	LEGDD	TABLET2	STELAS	VDIMEN
	FCNTR1	ELASOO	GAUSS	LEGDDN	GNUE	
SEG17	IMAT	RENO	OUT5	SPEC	XSP4	INF5
	CWAX	PUTW	INELAS	LFONE	SUBNW1	SUBNW3
	READIN	EMATRX	SNIN	LEVDEN	AA0AA1	SIGMAC
	HOSEI	CONTUM				
SEG18	FCNTR2 TMF5NW GNUE4	FCNTR3 EVAPOF GNUE5	INELAD EVAPOM ED4SG	INELAO GNUE1 ED4SG1	GAUSSO GNUE2	GAUSS1 GNUE3
SEG19	FCNTR4	NGNPNA	NGFUNC	NPFUNC	NAFUNC	GALT
SEG20	OUT IOR	PCUT MASK	ADIE ENDFZA	HELGA	IAND	ZAID
SEG21	SNOUT	DRAG	ORDER	PUNSH	DTFPUN	FLTFX



## Appendix C List of Sample Input and Output

### C.1 Sample input list

```
.....*....1.....*....2.....*....3.....*....4.....*....5.....*....6.....*....7.....*....8

*HRUN  EFNAME=J9103,SPTOGE6,SIZE=20
*DISK F01
*DISK F02
*DISK F03
*DISK F04
*DISK PUNCH
*TAPE F08,J2608,ENDFB4,OLD,001566
*DISK F30
*DISK F31
*DISK F80
*DISK F81
*DISK F82
*DISK F83
*DISK F84
*DISK F85
*DISK F86
*DATA
    1   1192      3      1     1.0+8      10.0      0.0      0.0
  406      2      2     26      3     4       0      1      2      1      4,0+5
    1      1      1      1      1
  20     10      0
  33.0  55.93493  56.93539  55.93891  52.94065      0.0
  1.00E-03  4.65E-01  1.00      2.15      4.65      1.00E+01
  2.15E+01  4.65E+01  1.00E+02  2.15E+02  4.65E+02  1.00E+03
  2.15E+03  4.65E+03  1.00E+04  2.15E+04  4.65E+04  1.00E+05
  2.00E+05  4.00E+05  8.00E+05  1.40E+06  2.50E+06  4.00E+06
  6.50E+06  1.05E+07  1.50E+07
```

## C.2 Sample output list

\*\*\* STOG \*\*\*

### INPUT DATA

	MAIN NO.	LORDEN	IREN	SIGP	AJIN	RFACT	SFACT
1	1192	3	1	1.0E+08	10.0	0.0	0.0
IDTAP	MODE	MCODE	MAXG	IEU	I <sup>w</sup>	ISPEC	IPUN
406	2	2	26	3	4	0	2
LINK1	LINK2	LINK3	LINK4	LINK5			
5.9635E+03	1.0988E+01	5.6266E+01	1.1763E+00	1.8095E+00		1.4277E+00	
1.0362E+00	6.9315E+01	6.9315E+01	7.6572E+01	7.7140E+01		7.6547E+01	
7.6572E+01	7.7140E+01	7.6547E+01	7.6572E+01	7.7140E+01		7.6547E+01	
7.6572E+01	7.7140E+01	7.6547E+01	7.6572E+01	7.7140E+01		7.6547E+01	
7.6572E+01	6.1420E+00						

\*\*\* STOG \*\*\*

- - END/B - -  
TAPE NO. MATERIAL NO.  
406 1192  
- - MULTIGROUP - -  
CODE MATERIAL NO.  
GAM-2 970  
- - GROUP INFORMATION - -  
NUMBER 26  
HIGHEST INELASTIC 26  
LOWEST RESONANCE 1

GROUP	ENERGY RANGE	MULTIGROUP STRUCTURE GROUP	LETARGY RANGE	ENERGY RANGE	LETARGY RANGE
1	1.0500E+07 - 1.5000E+07	0.405 - 0.49	-0.405 - 0.49	2.1500E+03 - 4.6500E+03	7.673 - 8.445
2	6.5000E+06 - 1.0500E+07	0.49 - 0.53	-0.49 - 0.53	1.0000E+03 - 2.1500E+03	8.445 - 9.210
3	4.0000E+06 - 6.5000E+06	0.431 - 0.916	-0.431 - 0.916	4.6500E+02 - 1.0000E+03	9.210 - 9.976
4	2.5000E+06 - 4.0000E+06	0.916 - 1.386	-0.916 - 1.386	2.1500E+02 - 4.6500E+02	9.976 - 10.747
5	1.4000E+06 - 2.5000E+06	1.386 - 1.956	-1.386 - 1.956	1.0000E+02 - 2.1500E+02	10.747 - 11.513
6	8.0000E+05 - 1.4000E+06	1.956 - 2.526	-1.956 - 2.526	4.6500E+01 - 1.0000E+02	11.513 - 12.279
7	4.0000E+05 - 8.0000E+05	2.526 - 3.219	-2.526 - 3.219	2.1500E+01 - 4.6500E+01	12.279 - 13.050
8	2.0000E+05 - 4.0000E+05	3.219 - 3.912	-3.219 - 3.912	1.0000E+01 - 2.1500E+01	13.050 - 13.816
9	1.0000E+05 - 2.0000E+05	3.912 - 4.605	-3.912 - 4.605	4.6500E+00 - 1.0000E+01	13.816 - 14.581
10	4.6500E+04 - 1.0000E+05	4.605 - 5.371	-4.605 - 5.371	2.1500E+00 - 4.6500E+00	14.581 - 15.353
11	2.1500E+04 - 4.6500E+04	5.371 - 6.142	-5.371 - 6.142	1.0000E+00 - 2.1500E+00	15.353 - 16.118
12	1.0000E+04 - 2.1500E+04	6.142 - 6.908	-6.142 - 6.908	4.6500E+01 - 1.0000E+00	16.118 - 16.884
13	4.6500E+03 - 1.0000E+04	6.908 - 7.673	-6.908 - 7.673	1.0000E+03 - 4.6500E+01	16.884 - 23.026

\*\*\* STOG \*\*\*

WEIGHTING FUNCTION  
IS GENERATED AS FOLLOWS

ENERGY	WEIGHT								
9.9000E+04	1.0101E+03	4.0000E+05	2.5000E+06	4.6453E+05	2.5610E+06	5.2906E+05	2.5280E+06	9.9335E+05	2.6157E+06
5.9335E+05	2.6158E+06	6.4226E+05	2.1676E+06	7.5492E+05	2.5988E+06	8.5575E+05	2.5562E+06		
9.5638E+05	2.4968E+06	1.0822E+06	2.4058E+06	1.2402E+06	2.2752E+06	1.5553E+06	1.9892E+06		
1.8704E+06	1.7031E+06	2.1461E+06	1.4691E+06	2.6975E+06	1.0640E+06	3.0421E+06	2.0521E+07		
3.3867E+06	6.9634E+06	3.1175E+06	5.7085E+07	4.2483E+06	3.9640E+07	4.7848E+06	2.7563E+07		
5.3253E+06	1.9055E+07	5.9984E+06	1.1912E+07	6.6715E+06	7.4035E+08	7.5129E+06	4.0568E+08		
8.3553E+06	2.2099E+08	9.0061E+06	1.0259E+08	1.0458E+07	4.7351E+09	1.1772E+07	1.7887E+09		
1.3087E+07	6.7144E+10	1.4730E+07	1.5150E+10	1.4290E+10					

WEIGHTING FUNCTION  
INTERPOLATION TABLE

NBT	JNT	NBT	JNT	NBT	JNT	NBT	JNT
2	5	7	3	13	13	1	15
31	4						

\*\*\* STOG \*\*\*

RESOLVED THE FOLLOWING CROSS SECTIONS ARE ADDED TO THE SMOOTH VALUES TO ACCOUNT FOR RESOLVED RESONANCE CONTRIBUTIONS					
GROUP	N,GAMMA	FISSION	SCATTER	N,GAMMA	FISSION
	GROUP	SCATTER GROUP		SCATTER	
1	0.0	0.0	0.0	6.8004E+03	0.0
2	0.0	0.0	0.0	2.9744E-01	0.0
3	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	1.7	0.0
5	0.0	0.0	0.0	1.8	0.0
6	0.0	0.0	0.0	1.9	0.0
7	0.0	0.0	0.0	2.0	0.0
8	0.0	0.0	0.0	2.1	0.0
9	0.0	0.0	0.0	2.2	0.0
10	5.1388E-03	0.0	1.6273E+00	23	0.0
11	1.8087E-02	0.0	1.3791E+01	24	0.0
12	5.2003E-03	0.0	2.7732E+00	25	0.0
13	2.1782E-02	0.0	1.0075E+01	26	0.0

\*\*\* STOG \*\*\*

UNRESOLVED  
RESONANCE CALCULATION RESULTS  
NO UNRESOLVED RESONANCE DATA ON ENDF/B TAPE

\*\*\* STOG \*\*\*

NO DATA IN FILE 3 FOR MATERIAL 1192, REACTION TYPE 2<sup>3</sup>  
TAPE HAS BEEN SEARCHED TO MATERIAL 1192, FILE 3, REACTION TYPE 28

NO DATA IN FILE 3 FOR MATERIAL 1192, REACTION TYPE 2<sup>4</sup>  
TAPE HAS BEEN SEARCHED TO MATERIAL 1192, FILE 3, REACTION TYPE 28

NO DATA IN FILE 3 FOR MATERIAL 1192, REACTION TYPE 77  
TAPE HAS BEEN SEARCHED TO MATERIAL 1192, FILE 3, REACTION TYPE 91

NO DATA IN FILE 3 FOR MATERIAL 1192, REACTION TYPE 108  
TAPE HAS BEEN SEARCHED TO MATERIAL 1192, FILE 3, REACTION TYPE 251

\*\*\* ST0G \*\*\*

MULTI- GROUP	SMOOTH	ELASTIC	INELASTIC	N. P	N. D	TOTAL	N. GAMMA
1	2.851E+00	1.3888E+00	1.5835E+01	1.2311E+00	1.1857E+01	5.0446E+03	3.4470E+02
2	3.4894E+00	1.9584E+00	7.9151E+02	1.4519E+00	6.7443E+02	1.8285E+05	6.5702E+02
3	3.4894E+00	2.1566E+00	2.7687E+02	1.5028E+00	2.6371E+02	0.0	1.1294E+02
4	3.14517E+00	2.3183E+00	9.5532E+03	1.1238E+00	8.6866E+03	0.0	7.6044E+04
5	3.0689E+00	2.2639E+00	2.5773E+03	8.0046E+01	1.0914E+03	0.0	1.7447E+05
6	2.6694E+00	2.3117E+00	2.9220E+03	3.4922E+01	2.4866E+05	0.0	0.0
7	3.2913E+00	3.2862E+00	5.0265E+03	0.0	2.2611E+06	0.0	2.9055E+03
8	3.3377E+00	3.3320E+00	5.7200E+03	0.0	0.0	0.0	5.0242E+03
9	4.1522E+00	4.1463E+00	5.8863E+03	0.0	0.0	0.0	5.7200E+03
10	5.3707E+00	5.3591E+00	1.0909E+02	0.0	0.0	0.0	0.0
11	1.3779E+01	1.3773E+01	1.8087E+02	0.0	0.0	0.0	1.0909E+02
12	2.7982E+00	2.7931E+00	5.2003E+03	0.0	0.0	0.0	1.0876E+02
13	1.0091E+01	1.0075E+01	2.1782E+02	0.0	0.0	0.0	5.1003E+03
14	6.81515E+00	6.8089E+00	6.8004E+03	0.0	0.0	0.0	2.1782E+02
15	8.9115E+00	8.6123E+00	2.9900E+01	0.0	0.0	0.0	6.0044E+03
16	9.9032E+00	9.8876E+00	1.5576E+02	0.0	0.0	0.0	2.9900E+01
17	1.0971E+01	1.0944E+01	2.3044E+02	0.0	0.0	0.0	1.5576E+01
18	1.1374E+01	1.1340E+01	3.3833E+02	0.0	0.0	0.0	2.0442E+02
19	1.1448E+01	1.1398E+01	4.9612E+02	0.0	0.0	0.0	3.3833E+02
20	1.1471E+01	1.1400E+01	7.2885E+02	0.0	0.0	0.0	4.9612E+02
21	1.1501E+01	1.1400E+01	1.0699E+01	0.0	0.0	0.0	7.2865E+02
22	1.1557E+01	1.1400E+01	1.5689E+01	0.0	0.0	0.0	1.0699E+01
23	1.1639E+01	1.1400E+01	2.3032E+01	0.0	0.0	0.0	1.5689E+01
24	1.1738E+01	1.1400E+01	3.3833E+01	0.0	0.0	0.0	2.3042E+01
25	1.1896E+01	1.1400E+01	4.9612E+01	0.0	0.0	0.0	3.3833E+01
26	1.5399E+01	1.1400E+01	3.9966E+00	0.0	0.0	0.0	4.9612E+01
							3.9866E+00

RESONANCE INTEGRALS TO 0.4650 Ev

FISSION 0.0  
 CAPTURE 1.5726E+00  
 N. GAMMA 1.4603E+00  
 N. P 9.2193E-02  
 N. D 1.7914E-03  
 N. T 1.0603E-05  
 N. HE-3 8.3638E-06  
 N. ALPHA 1.8094E-02  
 N. 2ALPHA 0.0  
 SCATTER 1.3599E+02

\*\*\* STOG \*\*\*

## ELASTIC SCATTERING MATRICES

SINK GPS	P0	P1	P2	P3
SOURCE GROUP	26			
26 SINK GPS	1.1334E+01	4.7646E-01	1.9197E-03	7.0000E-06
25 SINK GPS	P0	P1	P2	P3
25 SINK GPS	1.0869E+01	9.3033E-01	1.3108E-02	5.6111E-05
26 SINK GPS	5.3139E-01	-5.1852E-01	-1.2782E-02	-5.6111E-05
24 SINK GPS	P0	P1	P2	P3
24 SINK GPS	1.0868E+01	9.3050E-01	1.3111E-02	5.6169E-05
25 SINK GPS	5.3157E-01	-5.1869E-01	-1.2786E-02	-5.6169E-05
23 SINK GPS	P0	P1	P2	P3
23 SINK GPS	1.0873E+01	9.2651E-01	1.3014E-02	5.5737E-05
24 SINK GPS	5.2748E-01	-5.1470E-01	-1.2687E-02	-5.5737E-05
22 SINK GPS	P0	P1	P2	P3
22 SINK GPS	1.0869E+01	9.3033E-01	1.3106E-02	5.6151E-05
23 SINK GPS	5.3139E-01	-5.1852E-01	-1.2782E-02	-5.6151E-05
21 SINK GPS	P0	P1	P2	P3
21 SINK GPS	1.0868E+01	9.3050E-01	1.3112E-02	5.6169E-05
22 SINK GPS	5.3157E-01	-5.1869E-01	-1.2786E-02	-5.6169E-05
20 SINK GPS	P0	P1	P2	P3
20 SINK GPS	1.0873E+01	9.2651E-01	1.3014E-02	5.5737E-05
21 SINK GPS	5.2748E-01	-5.1470E-01	-1.2687E-02	-5.5737E-05

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```
*****  
* NEUTRON DISPLACEMENT CROSS SECTION *  
*****  
*** REQUESTED CORE = 3291 ***
```

## INPUT DATA

```
LNUO (NUMBER OF ANGLE MESH) = 20  
NEPOINT (NUMBER OF ENERGY MESH) = 10  
ED (EFFECTIVE DISPLACEMENT ENERGY) = 33.00 EV  
EMINNN (THRESHOLD ENERGY OF (N,N-PRIME)-EVAPORATION MODEL) = 4,531.00E+06 EV  
EMINNN2 (THRESHOLD ENERGY OF (N,N-PRIME)-IN MODEL) = 1,120.40E+07 EV  
AM (MASS OF THIS MATERIAL) = 55.934920  
AMNG (MASS OF NUCLEUS THAT IS PRODUCED BY (N,GAMMA)) = 56.935390  
AMNP (MASS OF NUCLEUS THAT IS PRODUCED BY (N,P)) = 55.938910  
AMNA (MASS OF NUCLEUS THAT IS PRODUCED BY (N,ALPHA)) = 52.940650  
AMHF (ENERGY RELEASE FROM FISSION (MEV)) = 0.0  
( AM,AMNG,AMNP,AMNA = CARBON UNIT )
```

## ENDFB DATA

```
AWR (MASS OF THIS MATERIAL (NEUTRON UNIT)) = 55.36  
ZA (ATOMIC NUMBER) = 26.00  
NSKIP(1) (MF=,MT=91) = 1  
NSKIP(2) (MF=2,MT=1) = 1  
NSKIP(3) (MF=3,MT=102) = 1  
NSKIP(4) (MF=4,MT=103) = 1  
NSKIP(5) (MF=5,MT=107) = 1  
NSKIP(6) (MF=6,MT=18) = 0  
ED/GAMMA = 0.47341026E+03EV  
(IF NSKIP(1) IS EQUAL TO ONE THAT CORRESPONDING X=SEC EXISTS.)
```

## NEUTRON DISPLACEMENT CROSS SECTION

(N,N)

RBAR-CROSS SECTION										
1	0.56114867E+03	2	0.42335572E+03	3	0.45586004E+03	4	0.56226229E-03	5	0.44535099E+03	6
7	0.17505621E+03	8	0.99059779E+02	9	0.55776855E-02	10	0.2817226E+02	11	0.13749453E+02	12
13	0.00874276E+01	14	0.14341728E+01	15	0.21879733E+00	16	0.16848709E+00	17	0.0	0.65271283E+01
19	0.0	21	0.0	22	0.0	23	0.0	24	0.0	0.0
25	0.0	26	0.0							

FBAR-CROSS SECTION ← Displacement Cross Section										
1	0.7712681E+03	2	0.83886087E+03	3	0.92341408E+03	4	0.11169435E+04	5	0.10776312E+04	6
7	0.48816933E+03	8	0.28036955E+03	9	0.17450450E+03	10	0.19361732E+03	11	0.20358651E+03	12
13	0.32058884E+02	14	0.97942154E+01	15	0.52416001E+01	16	0.16178088E+01	17	0.0	0.16727133E+02
19	0.0	20	0.0	21	0.0	22	0.0	23	0.0	0.0
25	0.0	26	0.0							

HBAR-CROSS SECTION ← Heat Generation Coefficient										
1	0.9643628E+05	2	0.94460159E+05	3	0.10255427E+06	4	0.12142958E+06	5	0.111242958E+06	6
7	0.5853761E+05	8	0.25220049E+05	9	0.1519858E+05	10	0.16395612E+05	11	0.16674556E+05	12
13	0.27266360E+04	14	0.77119391E+03	15	0.44467392E+03	16	0.23123900E+03	17	0.12312415E+03	18
19	0.27756158E+02	20	0.12876915E+02	21	0.59692805E+01	22	0.27161056E+01	23	0.12876917E+01	24
25	0.27761066E+00	26	0.30016265E+00							

\*\*\* STOG \*\*\*

N=2N SCATTERING PROBABILITY MATRIX  
AFTER HENORMALIZATION

EXIT GROUP	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
0.0	0.0	0.0	0.0	1.1046E-03	1.3855E-02	2.5111E-02	1.0703E-02	7.4642E-03	3.9933E-03	1.8660E-03	6.5838E-04	3.9933E-04	1.8660E-04	8.5838E-05	3.9933E-05	1.8660E-05	8.5838E-06	3.9933E-06	1.8660E-06	8.5838E-07	3.9933E-07	1.8660E-07	8.5838E-08	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

\*\*\* STOG \*\*\*

## MAIN DIAGONAL ELEMENTS (INGROUP SCATTER)

0.0

## COLUMN SUMS

6.5702E+02

\*\*\* F(E)=0, FOR ALL E, \*\*\*

\*\*\* STOG \*\*\*

INELASTIC SCATTERING PROBABILITY MATRIX  
AFTER RENORMALIZATION

EXIT GROUP	1.4897E-01	1.6530E-01	1.5169E-01	2.5786E-01	4.3598E-01	4.3070E-01
2	2.4137E-01	3.1116E-01	4.1218E-01	4.1116E-01	4.2562E-01	4.2105E-01
3	2.6561E-01	3.1214E-01	4.2293E-01	2.9114E-01	1.2621E-01	1.0742E-02
4	2.9700E-01	4.1218E-01	4.2293E-01	2.1621E-01	2.1621E-01	2.1205E-01
5	1.1433E-01	2.1621E-01	1.3721E-01	1.3721E-01	1.109E-01	1.5134E-02
6	4.3452E-02	1.2224E-01	1.2224E-01	1.2224E-01	6.1662E-02	6.7165E-02
7	1.3768E-02	4.9811E-02	5.7194E-02	5.2149E-02	2.5598E-02	2.6935E-02
8	2.4830E-03	1.7194E-02	9.1987E-03	2.5598E-02	1.1609E-02	5.7153E-03
9	1.3355E-03	9.1987E-03	4.2944E-03	1.1609E-02	5.2737E-03	2.7332E-04
10	6.2114E-04	1.9773E-03	2.4994E-03	1.2038E-03	1.2038E-03	1.0791E-02
11	2.8600E-04	1.9773E-03	5.2737E-03	5.2737E-03	5.7336E-05	7.7239E-03
12	1.3355E-04	9.1987E-04	2.4994E-04	2.4994E-04	2.5394E-04	3.5933E-03
13	6.2114E-05	4.2944E-04	1.21367E-03	1.1367E-03	5.2030E-05	2.4192E-06
14	2.8600E-05	1.9773E-04	5.2221E-04	5.2221E-04	8.9084E-06	1.6791E-03
15	1.3355E-05	9.1987E-05	2.4887E-04	2.4887E-04	0.0	7.7240E-04
16	6.2114E-06	4.2944E-05	1.1349E-04	1.1349E-04	0.0	3.5933E-04
17	2.8600E-06	1.9773E-05	5.2057E-05	5.2057E-05	0.0	1.3024E-04
18	1.3355E-06	9.1987E-06	2.4887E-05	2.4887E-05	0.0	0.0
19	0.0	4.2944E-06	1.1349E-05	1.1349E-05	0.0	0.0
20	0.0	1.9773E-06	5.2057E-06	5.2057E-06	0.0	0.0
21	0.0	0.0	2.4887E-06	2.4887E-06	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0

\*\*\* STOG \*\*\*

	MAIN DIAGONAL ELEMENTS (INGROUP SCATTER)	COLUMN SUMS	
8.0779E-02	7.9461E-02	1.0399E+01	1.1134E+01
1.2311E+00	1.4519E+00	1.5028E+00	1.1238E+00

1.1134E+01 1.2638E+01 0.0046E+01 3.4922E+01

## NEUTRON DISPLACEMENT CROSS SECTION

JAERI-M 6935

(N,N-PRIME)- DISCRETE MODEL

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THET(N)=

0, 8460000E+06	0, 14080000E+07
0, 3119000E+07	0, 31220000E+07
0, 3600000E+07	0, 36050000E+07
0, 4099000E+07	0, 41160000E+07
0, 4453000E+07	0, 45050000E+07

(N,N-PRIME)- DISCRETE MODEL

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RBAR=CROSS SECTION

1 0,25501965E+04	2 0,16999430E+04	3 0,10624435E+04	4 0,76844229E+03	5 0,26540000E+07	6,29390000E+07
7 0,0	8 0,0	9 0,0	10 0,0	11 0,0	0,29570000E+07
13 0,0	14 0,0	15 0,0	16 0,0	17 0,0	0,34450000E+07
19 0,0	20 0,0	21 0,0	22 0,0	23 0,0	0,34500000E+07
25 0,0	26 0,0				0,40400000E+07

FBAR=CROSS SECTION

1 0,37754122E+03	2 0,81374110E+03	3 0,13864899E+04	4 0,87323653E+03	5 0,43228997E+03	6 0,75047472E+02
7 0,0	8 0,0	9 0,0	10 0,0	11 0,0	12 0,0
13 0,0	14 0,0	15 0,0	16 0,0	17 0,0	18 0,0
19 0,0	20 0,0	21 0,0	22 0,0	23 0,0	24 0,0
25 0,0	26 0,0				

HBAR=CROSS SECTION

1 0,54131876E+05	2 0,10139739E+06	3 0,15621675E+06	4 0,93864426E+05	5 0,44058541E+05	6 0,71927039E+04
7 0,0	8 0,0	9 0,0	10 0,0	11 0,0	12 0,0
13 0,0	14 0,0	15 0,0	16 0,0	17 0,0	18 0,0
19 0,0	20 0,0	21 0,0	22 0,0	23 0,0	24 0,0
25 0,0	26 0,0				

\*\*\* F(E)=0 ,FOR ALL E. \*\*\*

(N,N-PRIME)- EVAPORATION MODEL

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RBAR=CROSS SECTION

1 0,0	2 0,0	3 0,0	4 0,0	5 0,0	6 0,0
7 0,0	8 0,0	9 0,0	10 0,0	11 0,0	12 0,0
13 0,0	14 0,0	15 0,0	16 0,0	17 0,0	18 0,0
19 0,0	20 0,0	21 0,0	22 0,0	23 0,0	24 0,0
25 0,0	26 0,0				

FBAR=CROSS SECTION

1 0,0	2 0,0	3 0,0	4 0,0	5 0,0	6 0,0
7 0,0	8 0,0	9 0,0	10 0,0	11 0,0	12 0,0
13 0,0	14 0,0	15 0,0	16 0,0	17 0,0	18 0,0
19 0,0	20 0,0	21 0,0	22 0,0	23 0,0	24 0,0
25 0,0	26 0,0				

HBAR=CROSS SECTION

1 0,0	2 0,0	3 0,0	4 0,0	5 0,0	6 0,0
7 0,0	8 0,0	9 0,0	10 0,0	11 0,0	12 0,0
13 0,0	14 0,0	15 0,0	16 0,0	17 0,0	18 0,0
19 0,0	20 0,0	21 0,0	22 0,0	23 0,0	24 0,0
25 0,0	26 0,0				

## (N,GAMMA)

HBAR=CROSS SECTION  
 1 0.1295036E+04 2 0.11029442E+04 3 0.76005493E+03 4 0.52942094E+03 5 0.34117068E+03 6 0.21305089E+03  
 7 0.14653488E+03 8 0.61596144E+02 9 0.3483732E+02 10 0.20273665E+02 11 0.13243881E+02 12 0.98730262E+01  
 13 0.83963140E+01 14 0.21569197E+01 15 0.72142383E+01 16 0.70551926E+01 17 0.69809335E+01 18 0.69465399E+01  
 19 0.69306738E+01 20 0.0 21 0.0 22 0.0 23 0.0 24 0.0

## FBAR=CROSS SECTION

1 0.3402770E+00 2 0.38785594E+00 3 0.41475081E+00 4 0.44256714E+00 5 0.50660197E+00 6 0.61795025E+00  
 7 0.6557397E+00 8 0.35232881E+00 9 0.20563397E+00 10 0.2285168E+00 11 0.23954085E+00 12 0.51342510E+01  
 13 0.14070874E+00 14 0.51390071E+01 15 0.21570447E+01 16 0.10989406E+00 17 0.1085130E+00 18 0.3502072E+00  
 19 0.30384415E+00 20 0.0 21 0.0 22 0.0 23 0.0 24 0.0

## HBAR=CROSS SECTION

1 0.46443027E+02 2 0.42523409E+02 3 0.43131974E+02 4 0.44875444E+02 5 0.48570883E+02 6 0.57198567E+02  
 7 0.5974981E+02 8 0.443132E+02 9 0.17277921E+02 10 0.18393384E+02 11 0.19471901E+02 12 0.41334213E+01  
 13 0.14468586E+02 14 0.41027541E+01 15 0.17196538E+03 16 0.87561320E+01 17 0.12801073E+02 18 0.18715055E+01  
 19 0.2178934E+02 20 0.40167275E+02 21 0.58949253E+02 22 0.86421766E+02 23 0.12691109E+03 24 0.18633442E+03  
 25 0.27323180E+03 26 0.22021311E+04

## (N,P)

## RBAR=CROSS SECTION

1 0.13378805E+05 2 0.11256168E+05 3 0.10071990E+05 4 0.88009109E+04 5 0.72032421E+04 6 0.55198007E+04  
 7 0.36647244E+04 8 0.21232373E+04 9 0.11994154E+04 10 0.62478728E+03 11 0.30914114E+03 12 0.15076812E+03  
 13 0.7910889E+02 14 0.34896393E+02 15 0.1666616E+02 16 0.79394419E+01 17 0.3751778E+01 18 0.1785364E+01  
 19 0.8430804E+00 20 0.956884E+00 21 0.18620266E+00 22 0.87639945E+01 23 0.41033917E-01 24 0.19232450E-01

## FBAR=CROSS SECTION

1 0.14628671E+04 2 0.75971561E+03 3 0.26561082E+03 4 0.76528589E+02 5 0.78686464E+01 6 0.13515523E+00  
 7 0.87408663E-02 8 0.0 9 0.0 10 0.0 11 0.0 12 0.0  
 13 0.0 14 0.0 15 0.0 16 0.0 17 0.0 18 0.0  
 19 0.0 20 0.0 21 0.0 22 0.0 23 0.0 24 0.0  
 25 0.0 26 0.0

## HBAR=CROSS SECTION

1 0.16292962E+07 2 0.45275909E+06 3 0.11548956E+06 4 0.25364796E+05 5 0.19626366E+04 6 0.262232815E+02  
 7 0.13641273E+01 8 0.0 9 0.0 10 0.0 11 0.0 12 0.0  
 13 0.0 14 0.0 15 0.0 16 0.0 17 0.0 18 0.0  
 19 0.0 20 0.0 21 0.0 22 0.0 23 0.0 24 0.0  
 25 0.0 26 0.0

## (N,ALPHA)

HBAR=CROSS SECTION  
 1 0.12299564E+05 2 0.11374619E+05 3 0.10277612E+05 4 0.91447224E+04 5 0.77485074E+04 6 0.63550154E+04  
 7 0.50592899E+04 8 0.3164037E+04 9 0.3164037E+04 10 0.2792062E+04 11 0.26102924E+04 12 0.35203038E+04  
 13 0.24779971E+04 14 0.24489061E+04 15 0.24489061E+04 16 0.24446276E+04 17 0.24446276E+04 18 0.24417057E+04  
 19 0.24412773E+04 20 0.24410776E+04 21 0.244093851E+04 22 0.24409423E+04 23 0.24409223E+04 24 0.24409131E+04

## FBAR=CROSS SECTION

1 0.42741805E+03 2 0.12846894E+03 3 0.78635980E+01 4 0.15978492E+00 5 0.0 6 0.0  
 7 0.0 8 0.0 9 0.0 10 0.0 11 0.0 12 0.0  
 13 0.0 14 0.0 15 0.0 16 0.0 17 0.0 18 0.0  
 19 0.0 20 0.0 21 0.0 22 0.0 23 0.0 24 0.0  
 25 0.0 26 0.0

## HBAR=CROSS SECTION

1 0.37416060E+06 2 0.79367734E+05 3 0.3594448133E+04 4 0.56607065E+02 5 0.0 6 0.0

7	0.0	6	0.0	9	0.0	10	0.0	11	0.0	12	0.0
13	0.0	14	0.0	15	0.0	16	0.0	17	0.0	18	0.0
19	0.0	20	0.0	21	0.0	22	0.0	23	0.0	24	0.0
25	0.0	26	0.0								

## TOTAL FBAR-HBAR CROSS SECTION

TOTAL FBAR-CROSS SECTION

1	0.30394899E+04	2	0.25371944E+04	3	0.25837932E+04	4	0.20673180E+04	5	0.15182964E+04	6	0.63893291E+03
7	0.48881382E+03	8	0.28072248E+03	9	0.1747056E+03	10	0.1938E+017E+03	11	0.2032605E+03	12	0.1677847E+02
13	0.32229593E+02	14	0.98456056E+01	15	0.73988448E+01	16	0.17277028E+01	17	0.16085130E+00	18	0.23502072E+00
19	0.34364415E+00	20	0.0	21	0.0	22	0.0	23	0.0	24	0.0
25	0.0	26	0.0								

TOTAL HBAR-CROSS SECTION

1	0.17917014E+07	2	0.728022687E+06	3	0.37789620E+06	4	0.24081727E+06	5	0.15849933E+06	6	0.62802487E+05
7	0.45912100E+05	8	0.255604480E+05	9	0.15214136E+05	10	0.1641005E+05	11	0.16594027E+05	12	0.1541976E+04
13	0.25411046E+04	14	0.75296666E+03	15	0.46639390E+03	16	0.24699463E+03	17	0.1353489E+03	18	0.70005245E+02
19	0.55135093E+02	20	0.5304419E+02	21	0.64918533E+02	22	0.89197872E+02	23	0.12819864E+02	24	0.18693135E+02
25	0.27320941E+03	26	0.22021611E+04								

\*\*\* ANISN OUTPUT PO \*\*\*

\*\*\* GROUP 1 \*\*\*

3.0395E+03	2.7917E+06	1.5835E-01	0.0	2.8517E+00	1.4087E+00	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

\*\*\* GROUP 2 \*\*\*

2.5372E+03	7.2803E+05	7.9157E-02	0.0	3.4894E+00	1.9674E+00	2.0982E-01	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

\*\*\* GROUP 3 \*\*\*

2.3938E+03	3.7790E+05	2.7682E-02	0.0	3.6864E+00	2.1662E+00	2.3577E-01	2.4137E-01	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

\*\*\* GROUP 4 \*\*\*

2.0573E+03	2.4082E+05	9.5533E-03	0.0	3.4517E+00	2.2858E+00	3.5160E-01	3.5169E-01	0.0	0.0	0.0
2.8578E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

SUPERTOG --- END